THE BRIDGE

BY FRANK BRANGWYN
& CHRISTIAN BARMAN

THE BRIDGE

BRIDGE OF ALI-VERDI KHAN, ISPAHAN, PERSIA

THE BRIDGE

A CHAPTER IN THE HISTORY OF BUILDING

Illustrated in Colour and Black and White by

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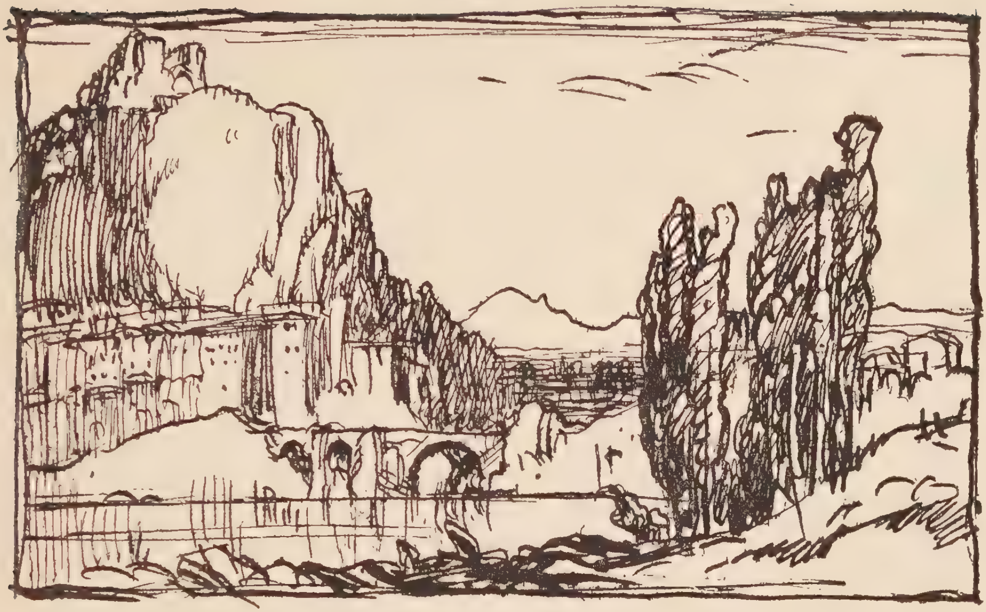

PREFACE

THE sub-title of the following essay (which, I have no doubt, contains passages that stand in need of corroboration and as many that invite stricture or denial) will explain much of its origin and even of its purpose. It is my fond hope to trace, in leisure to come, the growth of European architecture by following some of the clues here tentatively unwound. No fitter pretext is, I am sure, imaginable for such an experiment than that afforded by my present subject. Let me, without anticipating the argument proper to one of the ensuing chapters, summarize the reasons for this aptness.

A work of art consists of subject and form, each of which components may be again split up into a dual subdivision of

its own. Now the scope of subject is the scope of all human thought and, I suppose, emotion too. In most works of art subject and form are intricately connected, hence it is so often well-nigh impossible to put either of these alone under a minute and impartial examination. Such an examination will be the more feasible not in works wherein subject and form are separate entities, for such works do not exist, but in those wherein the subject is simple and—more important still—as nearly as possible constant. Now there are many sorts of houses, of books, of wearing apparel, all differing according to their subject, and it is to be noted that this subject is as a rule a highly complex one. The subject of a bridge, however, is plain, and it also remains perennially unchanged. Every child knows what a bridge is for, and knows, too, that (unlike a house, which gives warmth to the Englishman, coolness to the Spaniard) in all places and at all times it does the same thing. We are left free, therefore, to talk about its form as much and to look at it as closely as we please.

In pursuing this inquiry we shall find the bridge peculiarly helpful in yet another way. Like its fellow-subject (here almost entirely unregarded), form may be viewed from two distinct angles. From one we may perceive it in its purity, we may see and compute its face value (a phrase first used by Professor Lascelles Abercrombie to define the basis of æsthetic experience), while from the other the actual useful value of form is revealed to us. The distinction between these two is, of course, the distinction, present not only in most works of art but in all subjects of human experience, which *e.g.* in architecture divides structure from æsthetic. The fiduciary metaphor is as illuminating as any. What the pound sterling is to me, an " ordinary man," inexpert in the mysteries of purchasing power, a house or a bridge is to

my æsthetic consciousness, no less inexpert in the lore of building. Fortunately there are individuals who can compute the working value, at any precise moment, of the bridge as of the sovereign, and that whether it be found in London, Paris or New York. Indeed, though the face value remains constant, the useful value is ever changing; differences of time and place suscitate in it a dual and unceasing movement. I read in a recent architectural work that brick houses built in Essex clay have cracked with the movement of the shrinking soil. Thus in summer-time in Essex the useful value of a brick structure suffers a rapid decline. Do we find its face value similarly impaired? It is a platitude that the two cannot be entirely dissociated from one another, and indeed with the disappearance of an absolute geometry the belief in an absolute æsthetic has but a meagre excuse.

The following pages, nevertheless, proceed on the assumption that though the face value of a work of architecture may occasionally be even annihilated by a change (an error, if you will) of place, it is immune from temporal fluctuations. The assumption is justifiable, for it has had the support of most of our poets, from Shakespeare to Keats. What could be more natural, then, that I should apply the expository method to the æsthetics of bridges, reserving the historical for their structure? Yet this is to run contrary to the usual practice. Most works on architectural matters choose to enjoy the architectural works of mankind while skimming rapidly down the evolutionary stream. Structure, on the other hand, is commonly approached, though I do not deny that its scientific exponents may know better, in the deferential attitude proper to the devotees of an inspired religion. Its magic formulas have the virtue of an incantation, the finality of an esoteric doctrine. We have been told that there is no such thing as the history of science: there

is only Science. To say that there is no such thing as the history of art would, if indeed there are degrees of truth, bring us considerably nearer to reality. Neither statement is, of course, completely true. But I am only repeating what has been claimed often and adequately enough when I point out that, if the evolutionary approach may be fallacious in its premisses and mischievous in its result, it is never more fallacious or more mischievous than when it is directed towards the elucidation of æsthetic phenomena, the computing of face-values. "Biologists," an eminent scientist has (rightly or wrongly) told us, "exclude mind and design." The reader, will, therefore, scarcely be surprised that the second half of this study, which deals with mind and design, should purposely exclude the idea of biological development.

Still, development is a fact which has to be recognized, and the first six chapters attempt to recognize it in the sphere which, to my belief, is more rightfully its own. If the beauty of the plant is something outside and beyond its mere growth, something of which but few origins are to be found in its metabolism, the structure, the organs, of that plant on the other hand may quite legitimately be considered a product of such growth. What Mr. Geoffrey Scott has, in the lucid and authentic world of æsthetic face-values, denounced as "the biological myth," becomes, within the boundary of the working values of, let us say, structure, a piece of significant and perhaps even veracious history. But a thing can have no history which has no life of its own. Hence, for the purpose of the following argument, the separate individuality of the bridge as a structural organism is assumed.

It is a qualified individuality, however; the subject of a history is not completely autonomous, not abstracted from the surrounding universe. It grows, but its growth is conditioned by circumstances over which it has no control.

Movements are to be observed in it, but the movements obey a logical sequence forever inherent in the evolutionary idea. A purpose, no doubt, is entertained, but subject is not our present concern, except in one, and in one only, of its aspects. The only part of the subject of the bridge which is liable to much variation is (as will afterwards be more fully shown) that which decrees how long the bridge shall continue to perform its task. The factor of permanence, deriving entirely from the subject, is one of supreme, though as yet insufficiently recognized, importance in the study of useful form in architecture. A similar claim must, I am convinced, be made for the idea of velocity, which plays so conspicuous a part in the following chapters. To say that this idea has caused me no misgivings would be untrue, but the misgivings have been wholly on the score of its novelty, though at least one archæological observer, whose evidence I cite, has made register as a fact of what might else how easily be regarded as an hypothesis.

Little need be said about the rest of the book, except to ask the reader's indulgence should he deem some of the passages in Chapter VI unnecessary, a feeling for which he would deserve to be congratulated. The idea of an *old* bridge is so often steeped in sentiment, that of an *ugly* one in futuristic imbecility, that it appeared to me highly necessary, before proceeding to an analysis of beauty of form, to dissipate some of the errors that obscure our perception of it and tempt us to worship at less estimable shrines. Particularly necessary, indeed, in passing from the study of strength to that of form. The reason is not far to seek. In the province of strength there is just as much of good and bad as in the province of form, but there these opposite elements may safely be left to take care of themselves. We know very well that where it is a question of strength the good

will triumph over the bad without the judicial intervention of man's intelligence. Justice is there dispensed quite automatically, and perfectly too. If a bridge is deficient in *strength* it falls down, that is all, and there is no bridge left to tax our power of perception and judgment. What a pleasant world would be ours if the same law held sway in human society, causing crime to be instantly and unfailingly equivalent to suicide! Among bridges it does so operate. We are not called upon to criticize the *structure* of bridges. Now, it is evident that the man who desires to build a bridge will do well to acquaint himself with the elements of structural theory, but that is his business, not ours. We are called upon, however—and that most urgently and perpetually—to criticize *form*. The form of a bridge may be bad, may be execrable, and the bridge will not suffer thereby. Its strength will be in no manner impaired. But we will suffer, our strength will be impaired, our human dignity sullied, our human intelligence blunted and brutalized, if we do not take pains to obey the law that bids us discriminate between good and evil form. Well may we, as Voltaire tells us was the habit of Peter the Great, shudder as we pass over a bridge, though there are others that we might with more reason shudder to pass *under!*

The concluding epistle may appear to bear the same relation to the rest of the work that the sweet bears to the more substantial dishes by which it is preceded. It is, however, a little more than that. Rigorously objective as must be the setting-out of the main thesis, it was felt that a final glance, not at the bridge this time but *at the way the bridge strikes us*, became permissible even if it was not definitely called for. The stars that the Poet Laureate observes in the sky are not the same that are visible to the Astronomer Royal. The ones are human, the others

inhuman, and in the Epistle to Mr. Brangwyn some of the humanity that generations of men have infused into the idea of the bridge is allowed to flow back after having been so carefully excluded. But both here and elsewhere the essay has been as little encumbered with concrete examples as possible. Guide-books and works of local history are within everybody's reach, and most of my readers will, I am confident, find no difficulty in adding such examples as may be thought instructive. Surely in these days, when thought sometimes appears in danger of being extinguished in a plethora of detailed knowledge, it is safer to err on the side of economy and even reticence.

C. B.

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NOTE ON THE ILLUSTRATIONS

The drawings in this book are part of a great collection which Mr. Frank Brangwyn has been making for years past, with the idea of publishing a huge monumental work which was to include all the etchings which he has made of bridges at various times. The war, however, put an end to the whole scheme, for the enormous expense of producing such a work under post-war conditions put it quite outside the range of practical politics. The result has been that the etchings have been published at different times. Many of the drawings were used in *A Book of Bridges*, others in this work, while a great many have been sold and no record kept of them. So all that remains of the travels and labour of many years is represented by the work which is reproduced in the present book and *A Book of Bridges*.

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THE BRIDGE

CHAPTER I

§ I

WHAT is a bridge? The question appears simple, but there are several ways of answering it, and none of them is easy. Like all definitions, ours may be grouped roughly under two quite distinct heads, the descriptive and the explanatory. To describe a thing we need nothing but the evidence of our senses, though this evidence may have to be sifted and coordinated before it becomes adequate to our purpose. The pictures of specific bridges must be brought together and from them we must draw the elements of a general picture which will contain nothing that is not true of *all* bridges. To explain, however, is much more illuminating than merely to describe. What is the difference between these two? Let us take a common example: the leaf of a tree. We may describe this leaf in words that will promptly occur to us, but how may we explain it? One

important condition must be complied with if we are to do this: we must be familiar with the larger whole of which the leaf is a unit. Such a whole is the tree, and if we wish to explain the leaf we must study it with reference to this. Are we able to do as much for the bridge? Do we possess the requisite knowledge of the whole to which the bridge belongs? The bridge is a part of the *road;* once, therefore, we know something about the road we shall be able to give a proper explanation of the bridge also. Let us glance, therefore, at the function and behaviour of its progenitor.

The road itself need not be explained; we will take it for granted. It too is part of another and more comprehensive thing, the corporate civilization created by man. Its function amid that civilization is to provide the means of rapid and uninterrupted passage from one place to another. Passage of what? Thus far we need not look, for the nature and purpose of the things whose continuous motion the road makes possible has become an intricate study in itself. It is enough to speak of them as human beings with their chattels of various kinds. These creatures, by a motion of their own, generate upon the earth's surface a complex of lines that we know as roads. When such a road encounters an obstacle something peculiar happens; the road is stimulated to act in a special way, it has to set itself to overcome the obstacle. Sometimes even the obstacle is of such magnitude that the road ceases to exhibit its normal appearance, its conductive function being quite overshadowed by the new task to which it has for the moment to address itself.

This obstacle, this task, may be of two kinds. The obstacle may arise, first, from the constitution of the earth's surface. The firmness of this surface may be inadequate, and where this is so the road must out of its own substance add what is lacking. If it cannot do this it must look about for another

trajectory along which the important condition of proper support shall be fulfilled. A great marsh conquered is a triumph to be inscribed in a conspicuous place among the annals of road-making. This and other obstacles of *substance* are of considerable importance to the road-builder, but they need not concern us here, for the danger presented by a feeble material can only be averted by balancing the hidden weakness with hidden strength. No new formal entity is thereby called into being; for this we must look not to a suscitative condition of matter, but seek rather a *formal* origin.

The *shape* of the earth may indeed constitute a far more serious obstacle than its mere density of surface. It may be difficult enough to pick one's way across a bog, but it is not so difficult as to cross a mountain-range, or to clamber down one side of a ravine, working one's way up again on the other. I have suggested two examples which are typical of the groups into which the formal obstacles opposing the road's advance may be divided. The surface of the earth, of whatever density it be found, may be convex or concave, may raise up a barrier or dig a pitfall. Both inequalities must somehow be overcome by the line of the road. In what way is this to be done? Like all obstacles, these also may be met in two ways, strongly or weakly. They may be conquered or they may be circumvented; the path of the road may maintain its integrity, or it may be deflected to a course imposed by the nature of the obstacle. Let us first examine this second alternative.

Suppose the obstacle is a steep hill. The hill is more powerful than the road; hence a direct transcursion is impossible. Will the road make straight for its summit? No, the hill is steep, it is an adversary not lightly to be disposed of. The road will approach the summit by means of a series of oscillations exactly like those manifested in similar

circumstances by plants and animals. Perhaps I may mention one example of these, due to a distinguished Swiss biologist, whose inquiries into a series of phenomena grouped under the name of tropisms have yielded some fascinating observations. This scientist found that a butterfly flying in a straight line towards a source of light will, if that light be suddenly increased in intensity, break its course into a series of rising and falling waves. The road will approach the steep hill in the same way, with just such repeated turnings. So, too, does it plunge into a valley. This way and that way it swings until the top is reached, or the bottom, it matters not which, and the movements are continued on the opposite side, ceasing only when the obstacle is left behind and normal conditions prevail once more.

Such is the behaviour of a road when confronted with an obstacle more powerful than itself. Where, on the other hand, the road is the stronger it will of course pursue its way unyieldingly, cutting a passage for itself out of the crest of the hill, or even laboriously burrowing at its foot if the hill rises to a considerable height. A depression is traversed with perhaps less difficulty, for it is easier to build up an embankment than to cut a slice out of a mountain, or, *a fortiori*, than to tunnel one's way through the bosom of it. All three expedients are, however, directed to the same end, which is the integrity of the road, its freedom from distortions, vertical as well as lateral. But no road is absolutely straight from beginning to end ; moreover, though a road may run through an acclivity at one point it may shirk the task at another. The reason is that the inclination presented by the obstacles on its way is not the same throughout, the rise or fall is now steep, now easy. At one moment the inequalities of the ground are sudden enough to overwhelm the road and turn it aside, at another they are easily subdued with bank or

cutting. This is to say that in most roads oscillation and transcursion occur side by side.

It may be asked at what point the one of these will be visible, and at what the other. The conditions which cause transcursion to give way to oscillation are not of course strictly geographical; they do not reside in the conformation of the earth alone, nor even in the juxtaposition of its dual characteristics of shape and substance. The level of the earth and its bearing power are only one side of the picture; the road itself may exhibit varying degrees of *sensitiveness* and varying degrees of *strength*. Without going more deeply into the function of the road it may perhaps be as well to elucidate these qualities a little. The strength of the road, then, derives from the amount of traffic that passes over it; its sensitiveness from the velocity of this traffic. The first of these relations will be obvious to anyone, but the second may perhaps require an illustration. Let us imagine a road carrying a certain amount of traffic that proceeds at a rate of five miles per hour. The road encounters a hill with a gradient of one foot to every four. By changing from a forthright to an oscillatory movement it ascends this hill along an undulating line whose slope equals one in sixteen. Suppose the traffic along this road is increased in velocity though (a rare combination) not in bulk, travelling now at a speed of fifty miles an hour. The strength of the road will be no greater, but its sensitiveness will have become far more acute. Its only remedy is therefore to extend its oscillations, to increase the amplitude of its loops, to make its ascent a more gradual one, say at a rate of one in fifty. But if the amount of traffic grows apace with its velocity the strength of the road will be increased also, and instead of widening its oscillatory movement it will cease it altogether. This time it will cut itself a direct path through the hill.

These four factors it is, then, that by their interplay decide not only where oscillation shall yield place to a straight onward movement, but also at what point the oscillatory method of approach shall itself become necessary. Thus a hill such as has just been described might easily be ascended in a direct line by a bridle-path of little strength and low sensitiveness. The geographical irregularity and the sensitiveness of the road are alike too small for the irregularity to constitute an obstacle. The road glides over it with scarcely any sense of discomfort; no special activity is suscitated in it. Only when these factors reach a fixed minimum does the irregularity assume the character of an obstruction; only then does the necessity of combating it make itself felt. The behaviour of the road will depend upon the relation between these factors on the one hand and its own strength on the other. Unless, however, this minimum be attained its behaviour will manifest no change, will continue unaffected by geographical conditions. Is this statement universally true? It is true of all convex or rising irregularities, and it is also true of all concave ones save only those in the depth of which the movement of the road encounters another movement, primeval, irresistible, and running directly across its line of advance.

§ 2

Where flowing water is encountered all other geographical factors as well as those inherent in the road itself recede into the background. No matter how sensitive the road, it must not wind its way down the bank of a river and disappear. No matter how strong, it must not dam the waters of the stream, for the peril of the water is invariably, immitigably cumulative. The more you resist it the more it

grows. Its strength is infinite, but that of the road is only the strength of the human agency that gave it birth. If the road is to go on it can only do so upon one condition: it must not attempt to resist the motion of the water. The more it interferes with this motion the less will be its own security. "Pass and let pass" is the law which it must obey on the penalty of its life. How is it to combine these two precepts? How are road and stream to proceed on their way, each unhindered, each undiminished? To achieve this is obviously impossible. Road and stream alike must cling to the earth's surface; they are not like the birds of heaven whose paths may cross one another at different levels, nor are they like those twin triangles of Euclid's that enjoy the same pleasant freedom. It would be an exaggeration to call their world a two-dimensional one, but such a statement would yet contain a substantial truth. When the road raises itself to a higher plane its passage across the river will be not unlike the crossing of the paths of the two birds. But thus to take flight from the earth's surface is more than the road can do unaided. We have seen it dig its way through a protruding portion of that surface, and we have seen it thicken its substance so as to fill up a cleft, but its contact with the earth has been unbroken, it has still been nothing more than the line generated upon the earth's own surface by the movements of men and their belongings. To escape from this tyranny, to relinquish the unchanging contact with the earth, to raise itself above the earth's level, this is the function of architecture. And to enable the road to do this the help of architecture is required.

Many centuries elapsed, however, before the road was afforded this means of escape from its two-dimensional bondage. It must continue on its own plane, on the plane of the earth's surface; there it was that the problem had

to be solved, there and nowhere else the road must extricate itself from the perilous encounter. The cross-movement must be fought on its own ground—must be fought and, it has been concluded, must be yielded to, compromised with. For either of the two to continue unhindered and undiminished is out of the question; for the road, the weaker of them, to do this is especially impossible. It may be interesting to examine the various ways in which the problem has been solved and the compromise effected. As with the inequality of surface, so with the stream; the strength and sensitiveness of the road may be so inconsiderable that its trajectory will fail to suggest the presence of an obstacle except in one lesser point. I refer of course to a ford. In a ford the road will continue across the bed of the stream just as in an earlier example it continued across the summit of a hill, nowhere indicating that the hill or the stream (the instances are parallel) has been apprehended as an obstacle. Nowhere, that is, except in the choice of its point of attack. In flowing water a much more redoubtable opponent is found than in a ridge of earth, more redoubtable because in continual motion. While, therefore, the point at which a hilltop is to be traversed must be carefully chosen less the task be made unnecessarily arduous, the delving into a stream may end in disaster if the point from which it is ventured be an unsuitable one. Here is no oscillation, for the crossing itself proceeds in a straight line as though the stream mattered not one jot. But, before crossing, the road casts about for the most auspicious place, and thence takes its plunge without hesitation.

In this example the opposing force, together with the sensitiveness of the road, have not yet reached the minimum to which reference has previously been made. We will imagine both increased, and the strength of the road with them, in such a way that it is able properly to cope with the

problem. The river is too swift to be forded ; the traffic is too swift to proceed in such leisurely fashion. What did the road do in a similar position when the obstacle was a rise or fall in the ground ? Confronted with a fixed obstacle its movement was broken up into a series of oscillations. Confronted with a moving obstacle, such as a river, an oscillatory movement is not sufficient. The turning hither and thither is a sacrifice of time, of ultimate speed. What is required here is a sacrifice of space, of substance. The water has to pass, there is nothing for it, and to allow the water to pass the road must *break itself up*. There are two ways in which it may do this. It may, on the one hand, divide itself into a series of discontinuous fragments which remain motionless in the stream, and you have a row of stepping-stones. On the other hand, it may detach from itself one or more moving particles which travel to and fro across the water with a continuous motion from bank to bank. Where this occurs you have, of course, a ferry. And let us note an interesting point about such a ferry. Like the road, but unlike the stepping-stones, it is continuous, it is dynamic. In the ferry, therefore, we shall find once more the oscillatory movement that we observed in the road itself. Its path is a sigmoid curve, the amplitude of which varies as the strength of the current, and inversely as the strength of the craft. On just such a combination of factors, it will be recalled, did the amplitude of those other oscillations, those of the road ascending an incline, depend.

§ 3

The question asked at the beginning of the chapter has now been answered. We have watched the road in its progress across the landscape, and seen it pause at the river's

edge. Among the choice there presented to it two possible courses have been examined, and the second, that of division, has been found to admit of a dual interpretation. The fragments may be fixed and discontinuous, or they may be animated by a continuous motion backwards and forwards. Whichever of these be followed, the process of division can only be inflicted upon a road that is weaker than the stream. If the road be stronger it will command the aid of architecture and put forth a bridge. With which of the former lines of behaviour does the bridge claim kinship—in which lies its origin, in ferry or stepping-stones ? The answer may appear curious, for it derives from both at once. The bridge is the continuous suspended over the discontinuous. Its site is the site of the ferry, because the continuity of the ferry represents a more advanced stage in road development than do the stepping-stones, a stage which immediately precedes that other marked by the advent of the bridge itself. Its structure, however, is founded upon the discontinuous arrangement of the stepping-stones, for it is composed of a series of isolated piers. Between these piers the water flows, and above the aperture thus formed the road is supported on a beam or an arch.

These, then, are the two principal parts of a bridge ; the supporting pier, and the arch which enables the movement of the water to continue, not indeed as though no bridge had been there, but still with the smallest possible hindrance. What, it may be asked, of the roadway ? Is not this as truly a part of the bridge as the structure upon which it rests ? There are several reasons why the road should be refused a place in the following analysis. The road which constitutes the upper surface of a bridge is in no way unlike an ordinary road built on the solid earth. We have examined the road in its capacity of begetter ; as a constituent part of the bridge

it occupies a peculiar position to which we shall revert in the proper place. As a structural unit, however, it possesses but little interest.

It is plain from what has been said thus far that in these pages we need pay little or no regard to the bridge comprising one arch only. The reason for this is twofold. I need do no more than mention the first, which springs from the fact that this kind of bridge lacks that important element, the pier. The second reason is no less considerable. We are studying the evolution of the bridge as it proceeds under two kinds of influence, the natural and the functional—the external, one might say, and the internal. It will be seen that in the one-arch bridge the first of these influences assumes a preponderating place at the expense of the second. The dimensions and structure of the arch in a one-arch bridge are dictated almost exclusively by the width of the waterway, the proper morphological development counting for little. The one-arch bridge is therefore a very special kind of bridge which will cast scarcely any light at all upon the general problem we are examining. A bridge that is not a complex structure, a society of piers and arches, is of little use to us here.

These two, the pier and the arch, constitute our bridge. Like all dualities they are complementary and inimical to one another; the history of their quarrel is the history of the development of bridge forms. The one, a primary member, its function identical with the function of the bridge, stands for weight, strength, permanence. The other, which may be called secondary because its function is special and but indirectly connected with that of the bridge, stands for lightness, speed, security. In the pier the bridge conquers the stream, asserts itself, plants itself immovably in front of the adversary. In the arch it yields; the arch is the

compromise, the act of homage, call it what you will, without which the fury of the stream would at once rise up and destroy the bridge. Both are necessary; both continually attempt to extend their domain. I have said that their efforts to do this are the origin of the various kinds of bridges that have been built throughout the centuries. They would be exclusively so but for a third element which will be examined in the following chapter, an element which, deriving from the human agency whereby the bridge comes into being, will throw its weight upon the side of one of these conflicting members and cause the ultimate victory of this one over the other. Until this third element becomes of calculable importance, however, the field is clear for the two to fight it out among themselves. Which is to spread itself over the greater area, pier or arch? What are their several fortunes at this moment of clear, uncomplicated rivalry?

§ 4

The question is a difficult one to answer offhand. Both the pier and the arch are essential to the bridge's existence. If the pier is too small, the bridge will crush it or sink with it into the bed of the river. If the arch is too small the gathering force of the water will make short work with the bridge that stands in its way. Now either of the two can only increase its size at the expense of the other. For let it be understood that at the period of which I am speaking building technique is at any one moment a fixed and limited thing. You can build arches wide enough to bridge a given waterway in seven spans, say—not, quite definitely not, in five or six. To do this may become possible in ten, or fifty, or a hundred years; to-day it must be seven; to-day

the width of arch necessary to cross the obstacle in six spans cannot be built. Were this not so the statement I have just made would appear untrue. By crossing in six arches, the reader might say, instead of seven, you *could* increase the width of the arch without robbing the pier of a corresponding thickness. Now it will be shown in another place how an important law of growth runs counter to this plausible idea and prevents its taking effect even in historical sequence. It will then be found that though a bridge built fifty years later may have fewer and wider arches than its predecessors, the piers will *still* have grown narrower. But for the moment this must suffice: that the capacity of any particular period is such as to enable the bridge-builder to cross a river in just so many arches, but that round about this fixed span there is sufficient freedom for arch and pier to continue their dispute.

In the early mediæval bridge, which represents the initial stage of this dispute, the result is clear. The victory is to the first-comer. First the pier is begun, and from its sides, as soon as it has risen some distance out of the water, the arches spring. By this time the pier has broadened itself as much as it could desire. Suppose it has exceeded the bounds of prudence? Suppose the space left for the arch *is* too narrow? Very well, the first spate in the river will soon enough bring the fact to light, and pier and arch will disappear together. The mason who built the pier could not know the extent of the danger that might arise afterwards; only many years of experience, years of failure and defeat, will teach him *that*. The danger of subsidence, however, is present from the first. If the pier be insufficiently based upon the earth it will soon begin to sink into it. Against this danger the builders know better, know more immediately, how to guard. They build the piers broadly; the arch may,

and will, until bridge after bridge is swept away by the infuriated river, take care of itself.

They build the piers broadly, but volume is not necessarily allied to weight. It is possible to achieve the one while avoiding the other. To do this we need only build as we build in our own century, leaving everywhere great hollows, so that bulk may be obtained with but little mass of material. Do the mediæval bridge-builders make use of this expedient? Do they show any desire that the increased breadth of the pier shall not entail an equally increased weight? No, weight is indeed as precious to them as breadth itself. The pier must not only be as big as possible, it must also, strange though it may at first seem, be as heavy as possible. The reason is not far to seek. Most often they are building on a foundation that is by no means unyielding. Some subsidence there is bound to be. It may be little, or it may be much; whatever be the amount of subsidence, it will be roughly proportionate to the weight of the burden laid on the earth. Now there are a variety of these burdens to be considered, but we need concern ourselves only with two: the piers and the arch. Which is the heavier of these two? This is the one that will cause the earth to yield to the greatest extent.

Now supposing the pier alone, without the weight of the arch, is able to cause a certain subsidence. Suppose it sinks to a depth of eighteen inches. At that point it has found its level: thenceforward, if remaining alone, it will sink only in an infinitesimal degree. Now to add eighteen inches to the substance of a pier that has sunk is not a very difficult business. Let us imagine, however, that after the building of the arch one of the piers sustaining this arch, being on softer ground, sinks another eighteen inches under the added weight, while its companion shows a subsidence of not more than six.

PONTE DELLA MADDALENA IN THE PROVINCE OF LUCCA

Suppose a troop of soldiers march over the bridge, and the pier will thus be caused to sink yet deeper. It will be seen how important it is that the subsidence of the pier should be arrested at the earliest possible moment: that if it can be done, subsidences brought about by any other burden after the building of the pier should be avoided altogether. They can only be avoided (or, if not, minimized) by giving the pier the greatest possible weight. Compared to the weight of arch and roadway and the moving load, the weight of the pier must be such as to produce by itself the greatest possible amount of subsidence. Whatever sinking takes place must be made to precede, so far as possible, the building of the arch. In a word, the heavier the pier the deeper it will sink into the ground, and the less it is likely to sink afterwards under a provocation which becomes insignificant beside that contained in its own magnified weight.

The pier as broad and as heavy as it can be made: this is the first characteristic of the mediæval bridge. If we see a bridge of this period containing a wide arch and narrow pier we shall know that the pier has contracted only under the strictest compulsion. We shall know that there the stream may attain to such a redoubtable speed and volume that it would not tolerate another inch of masonry in its way. There is, for instance, the bridge across the Serchio at Lucca, depicted by Mr. Brangwyn, in which the small arch on the left (balanced on the opposite side by three decreasing arches which are not here shown) is only seventeen feet against the hundred and twenty of the great arch. Though this bridge is unusually narrow it has withstood the heaviest floods during its many centuries of existence. It could not have done this without the great middle arch. We may be certain that the bridge in this perilous spot has been cast down and rebuilt more than once before the present compromise was arrived at.

Clearly the water has said again and again : This arch is too narrow : down with you ! until at last it was pacified and could be induced to leave the bridge unscathed.

Always and everywhere as thick as the flow of the water will allow, narrowing only when forced to do so, yielding place to arch and river against its will and with effort : that is how the mediæval pier makes itself known. Fortunately this compulsory shrinkage is, where it becomes urgently necessary, usually assisted by natural conditions. Where the river is particularly swift and liable to sudden increase a rocky bottom is often found, upon which a firm support may be obtained with less breadth of foundation than would elsewhere be required. Were it not for this favourable circumstance there would have been no bridge at Lucca in mediæval times. Had the bed of the Serchio been no more substantial than the bed of the Thames the narrowing exacted by the rapid stream could not have been carried out. The narrow piers with their ample expanse of suspended masonry would have sunk and twisted and tumbled down in a very short time.

§ 5

This observation leads us to the next important characteristic of the mediæval bridge. The foundation may be of different kinds between one bridge and another, but this is not all : it may vary even along the path of one single bridge. A straight line drawn across the bed of the Thames will encounter varying degrees of solidity in the constitution of this bed. Now to pick out the most favourable of these must be the bridge-builder's first concern. The hardest material, the most faultless construction, avail nothing when they rest upon a yielding foundation : a circumstance which so profoundly affects the life and work of man that every language

in the world owes it what is perhaps its most significant and ineluctible—I had almost said fundamental—group of metaphors. A sandy foundation has become a synonym for all that is unstable, deciduous and threatened with the direst jeopardy. This certainly is true in the building of bridges. The first thing to be done, says Palladio, is " to pitch upon such a place as shall give ground to hope that the bridge may be perpetual." These places, as they are discovered throughout the breadth of the river, will not all be equal distances apart : these two will be closer together than those. We have here a second important characteristic of the early mediæval bridge : the inequality of the arches. Old London Bridge is an excellent example of such a structure, for the width of its greatest arch was almost double that of the smallest. This discrepancy did not trouble the twelfth-century bridge-builder. Where the bottom was suitable to receive a pier there he flung down his footings of great boulders, upon the top of which the square-wrought stones of the pier were set.

The bridge at Lucca, a yet more striking example, furnishes us with one more characteristic which, like the previous one, springs from the building of the pier though it is chiefly exhibited in another member. The diversity of spans is not haphazard. The greater spans indicate where difficulties have been encountered in laying a foundation, and these difficulties will generally be more acute in the middle of the stream than anywhere near its border. It follows, therefore, that the greatest arch will most often be found at, or near, the centre of the bridge. But a wider arch must also rise higher, hence the bridge will mount upward towards the middle. The bridge of unequal arches, it will be seen, is *humped :* the diversity of its arches is the measure of the elevation of this hump. The hump takes a long time to disappear ; the bridge of equal arches is a comparatively modern invention. Such a

bridge has of course a level roadway, but at the period of which I am speaking a level roadway is also occasionally found. It may namely occur in a bridge whose length is such that the variation of its arches fades into insignificance. The arches will then be adjusted to a uniform level throughout their great collective length. Several of these level bridges with more or less (never *quite*) equal arches antedate, in fact, the humped kind, and it would seem that the organizing of the variety of arch-openings into a whole dominated by a great central span is a process whose completion required some little time. But the adjustment has to be made here too, the increase in the width of the arches being not always as regular as might be desired.

There are, of course, several ways of effecting this adjustment. The problem, in its simplest form, is this: to make the arches of uniform height though of varying widths. If you begin with your widest arch you may raise the lesser ones to the same height by the most primitive of the various means of which we have the choice. We may, that is to say, make the smaller arches follow the same outline as the larger, curtailing them to make them fit into the narrower space, and causing them to spring from a point higher up the pier. To vary the springing heights is not, however, conducive either to strength of construction or to comeliness of design. A much more satisfactory way is to invent for every arch a separate curve, different from that of its neighbour, whose proportions are unlike its own. Satisfactory enough, but exceedingly difficult, since an arch whose outline is not part of a circle will require a variety of odd-shaped stones, each one having its sides normal to the wayward curve of which they form part. Parabola, catenary, ellipse, whatever this curve may be, it will present to the mason very stubborn difficulties indeed. No such difficulties are found in the

pointed arch, whose sides are each a part of a true circle. You may build twenty pointed arches, all of different widths, and the sides may be of the same curvature, and the stones of the same tapering form, in every one of them. Round the pointed crown as round an imaginary hinge the sides swing now apart, now together, and the arch adjusts itself to any variety of span that may be required of it.

§ 6

Thus far we have confined ourselves to those characteristics which spring from the manner of founding and building the pier. It was seen that the force of the waterway constituted an influence just as strongly formative, but one that did not make itself felt directly while the building went on. Its turn came later, it was a force that grew and abated with the seasons: the peril it held did not threaten the building of the bridge, it threatened its survival. The restraint put by it upon the growth of the piers has been noted. Has it left no more positive signs elsewhere?

There are two separate elements to be discerned in the danger of the waterway, similar to those that we found in the traffic flowing along the man-made road itself. There is, first, the *volume* of the water, and, secondly, its *velocity*. Each of these elements is withstood in its own way by a particular part of the bridge. The pier it is that has to resist the velocity, while the arch must be adequate to the volume, admitting as much of it as is at any time likely to be met with. Let us begin by examining the kind of bridge in which the waterway is apt to be most troublesome, the bridge standing in a rapid and variable stream upon a sound foundation of rock—the bridge, that is to say, in which the voids are greater

than the solids. First, the piers, which are comparatively slim and rise in an unbroken vertical line from their foundation, are made to present an acute angle to the motion of the water which it divides silently and easily like the prow of a ship. The greater the force of the water, the more the cutwater protrudes, the more acute its angle. The higher the level of the water is apt to rise, the higher will the buttress-like form of the cutwater be carried without diminution. In some mediæval bridges such as that at Durham, drawn by Mr. Brangwyn, and in many found in the mountainous regions of southern Europe, it ceases only at the top of the parapet. Sometimes the fear of being outwitted by the quickening currents is so strong that the whole bridge is brought forward to oppose them with a peaked angle pointing upstream, like the famous Pont St. Esprit and the bridge of Bénézet at Avignon, each of which is bent into halves that together form an obtuse angle. But such examples are few.

The peril that lurks in the waterway, the disruptive forces that cast themselves horizontally upon the bridge, could not be more effectually, more visibly opposed, and this first form of bridge with its tall and powerful cutwaters must remain the most characteristic example of what may be called the bridge militant. On the other hand, Mr. Brangwyn's view of the Pont Marie over the Seine at Paris shows the cutwaters finished halfway up the arch with one of those stepped conoidal copings which are a peculiar product of the French genius in bridge design. In such a structure as this the faces of the cutwaters are frequently curved and given the outline (on a horizontal plane) of the Gothic pointed arch, that is to say an arch circumscribed upon an equilateral triangle ; in some the faces meet in an angle that is yet more obtuse or sometimes even rounded off.

The early bridge is also distinguished from the later (whose

PONT MARIE, PARIS

forms never, as we shall see, possess quite the same functional directness) in that where the water flows one way only, or one way more than another, the cutwaters are less strongly developed on the downstream side. It may be that they do not rise so high as the others, as in the Pont Henri IV over the Vienne at Chatellereault, a charming late example inspired in this particular by mediæval experience. Here the cutwaters cease halfway and are very prettily surmounted by oval panels each bearing in its centre a ring and chain for mooring boats. Elsewhere the whole of the downstream cutwater will be given much less projection, being perhaps rounded or even square in outline. Further refinements of this kind do not come within the scope of this chapter ; but I may perhaps point to the arches of the modern bridge over the Garonne at Toulouse, whose ends are given a conoidal or funnel-like termination of the kind which has elsewhere been traced to another source, but which here is probably intended to allow of the freer passage of the water, another truly mediæval idea.

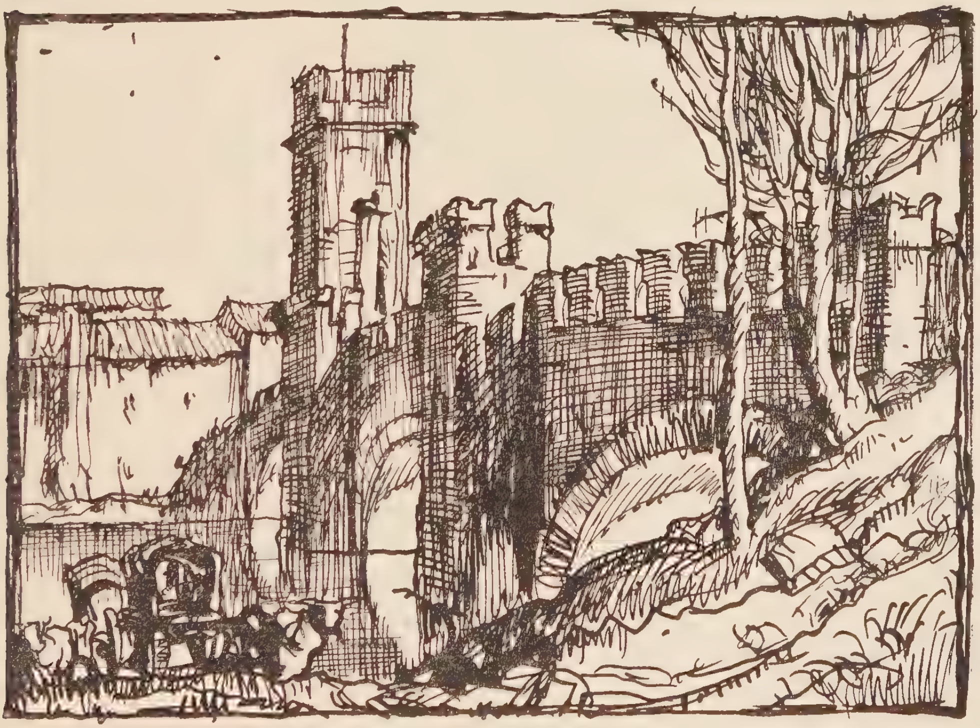
The danger arising from a sudden increase in the volume of the water is met in two ways : first in the formation of the main arches themselves, and secondly by the provision of relief arches to make up for the diminution of the large arches towards the top. For it is an unfortunate property of the ordinary arch that as the water's level rises towards its apex the opening grows narrower and narrower. To make this contraction of the width begin well above the normal level is an elementary precaution in bridge-building, while a designer who made his arches spring below this level would at all times be open to severe criticism. This important consideration at once puts a check on the widening of the span of the arches, for the wider the span the greater the height from springing to crown. Now it is clear that in a series of lesser arches, though their aggregate aperture at normal water-level will be con-

siderably less than that of a single arch possessing their combined span, the variation of this aperture will be much smaller for the different levels assumed by the water. It is for this reason that the large semicircular arch of the Roman and Renaissance bridge so often has its spandrils pierced by relief arches, which the French, whose bridge nomenclature is so much richer than ours, and at the same time so exquisitely picturesque, have given the beautiful name of *oeils de pont*. Mr. Brangwyn's drawing of the Persian bridge at Shuster shows these relief arches introduced between pointed bridge-arches, a combination which is less often met with.

It is less often met with for a very good reason. The purpose of the relief arch is to make up for the diminution of the width of the arch towards the top. Now the flatter an arch is the more rapid this diminution will be, whereas if its sides are steep they will approach each other with less suddenness. A pointed arch, if it belongs to the steep kind, will therefore present the most favourable of shapes where a slow and gradual diminution of the aperture is wanted. The water rising to half the height of a pointed arch will flow more freely than that which has reached a corresponding level in a semicircular one. Not only does the pointed arch, then, itself provide the security which the relief arch is designed to add to an arch of semicircular shape: it is in every way a form which must strongly commend itself to the mediæval builder endeavouring to withstand the inconstant movements of his stream.

Our picture has now gained something in precision. We have the tendency of the pier to take up as wide a space as it dare; we have the unequal distance between one pier and another, and the consequent inequality of the arches. Another concomitant of this unequal spacing is the humped outline of the roadway. Next there are the cutwaters, more pronounced

on the upstream side, and corresponding in height as in forward projection with the rapidity of the stream. A too wide arch may by its shape become a danger unless relief arches are pierced through the spandrils. Both for its adaptability to varying water-levels and for the ease with which it embraces varying widths of span the pointed arch is in favour with mediæval builders. Not that the reasons thus far noted for the prevalence of this arch are the only ones; they are, however, sufficient to allow us to deduce this prevalence. Pier and arch alike have thus far come within our purview, but we have only watched them combat the natural dangers that threatened the bridge. In the next chapter we will look whether the burden for which it is designed in its turn exerts a visible influence upon its structure.



CHAPTER II

§ 1

THERE are two things to be known about the burden imposed on the bridge if we are to gauge the influence of this burden upon the growth of the bridge-forms. In the first place, it is necessary for us to ascertain what sort of a burden it is the bridge has to carry. But this is not enough. We must also know for how long a period it is intended that the bridge shall carry this burden. In other words, the degree of permanence desired is as needful for our inquiry as the degree of strength.

This truth is one which has been often overlooked, and even where it is accepted its application remains vague and general in the extreme. Is permanence something real? Is it a quality possessed (to borrow the philosopher's jargon) of an objective existence? Few would deny that it is. And if it be granted that there is some such thing it will not, I think, be denied that it is exceedingly important, both to the object in which it resides and to the maker or owner of that object. Indeed, permanence has come to be at once the

outward symbol and the guarantee of that continuity about which Mr. Bernard Shaw some time ago became so deeply concerned that he made it the subject of five consecutive plays. "If you take a house on a ninety-nine years' lease," he causes one of his characters to reflect somewhere in this extraordinary cycle, "you spend a good deal of money on it. If you take it for three months you generally have a bill for dilapidations to pay at the end of them." What is true of the tenant of a house is even more profoundly true of the builder, for building a house is much more of an enterprise than repainting the front door, and putting in a new bath, and doing the hundred little things that Mr. Shaw conveniently describes as "spending money." "Give a man secure possession," says another writer, "of a bleak rock, and he will turn it into a garden; give him a nine years' lease of a garden, and he will convert it into a desert."

We are not concerned in these pages with the choice between a garden and a desert. But the time factor is one which cannot possibly be excluded from our argument about bridges. Every one must agree that a bridge-builder with secure possession will, with similar means at his disposal, put up a structure conspicuously different from that of his neighbour with a nine years' lease. Let us illustrate the profound importance of the time-factor by means of an example. The first English suspension bridge lasted sixty years. The river Meles in Asia Minor is crossed by a bridge which must have been of considerable antiquity when St. Paul passed over it into the town of Smyrna. We may roughly estimate its life at between thirty and forty times that of the suspension bridge. Now what is the corresponding variation observable in the domain of strength? Since the year 1924 all bridges forming part of what we call our main arterial roads are being built to carry a load of fifteen tons for each axle of the vehicles

that use them. Five tons was a common maximum a century ago, and even down to quite recent years. We here see a triplication of the requisite firmness in a short space of time. Even if we double this figure with an eye on our lighter country bridges of the Middle Ages we shall still be far from the enormous differences exhibited in the degree of permanence. Can it be doubted that a factor subject to such fluctuation carries with it outward signs of corresponding divergence? Is it other than reasonable that the permanence of a bridge should be looked upon as a formative influence of as much consequence as its strength?

§ 2

So much strength, of such a duration: here we have the dual aim pursued by the bridge-builder. His problem is now "posited." His conquest of space must be reinforced by an accompanying conquest in time. Let us examine both in turn. How (to begin) will the magnitude and the nature of the load influence the building of the bridge? It will be noted that the most important thing about the load is that it is an intermittent and a moving one. A bridge is not, like a building, put up to shelter people and their possessions. It is a burden-carrier only, and its burdens are peculiar in that they arrive suddenly and more quickly or slowly from one end of the bridge to the other. An arch is now pressed down, now free. The pressure is exerted again and again, and as it strikes the arch it travels along it, straining each of its parts in turn. It is a load that hits, not one that merely weighs; it partakes, therefore, of the nature of an impact. It is what engineers call a *live* load.

How is the bridge to receive this load? What will be its

behaviour? When we examined the behaviour of a road meeting with an obstacle we noted that it might be of two distinct kinds. The road, we found, could *yield* to the obstacle by means of a series of oscillations, or it could *overcome* it by pursuing its way unmoved. The position here is reversed. We do not see the bridge striking a foreign object, but we see such an object striking the bridge. The alternatives are, however, the same. The bridge, too, may choose between yielding and inflexibility, between an oscillatory motion and a firm resistance to motion. And as with the road, so here also the expenditure of strength required for each of these modes of behaviour is highly unequal. Far greater strength is required to resist than to yield. Let me cite a more conspicuous illustration to make this statement clear. If an express train dashes into a vertical face of rock there will be no yielding whatsoever: a firm resistance is opposed to its movement. Consequently the shock sustained by the obstacle will be equal to the force with which the train speeds forward. Imagine, on the other hand, such a train meeting with an obstacle that presents no resistance whatsoever. Such an obstacle (we are calling it an obstacle though it has done nothing to deserve the name) may be an utter vacuum. It may also be represented by another express train preceding the other by a few yards and going at precisely the same speed. In this example the obstacle yields so much that there is no shock at all: there is not even a contact. If, however, the first train is, at the moment when the second one appears, going at *half* the speed, it will after a little while be overtaken. There will be a shock this time, but it will not be of the same intensity as that wherewith the train hurled itself against the cliff. The rear of the first train will sustain an impact only half as severe as that suffered by the motionless mass of rock. The reason is that the first train yielded.

Let us transfer these ideas to a more homely plane. There we shall find, for example, that a piece of lead or indiarubber struck with a hammer will suffer less injury than a piece of glass similarly struck. Again, everybody knows that in walking across a plank one is much more safe if the plank yields under the foot than if it does not. The same is not true of a motionless load placed upon the plank : it is the moving load that makes all the difference, it is to this that the protective motion must answer. The moving load becomes less dangerous if the plank gives way ; the attack loses a proportion of its force by this compliant behaviour. But the plank must not only yield : it must also spring back when the person walking across it has gone. The piece of lead is still as whole as the indiarubber when it has been struck, but the indiarubber has sprung back and bears no trace of the hammer-blow. The lead, on the other hand, is somewhat flattened, and bids fair to remain flattened. Both lead and indiarubber were less *rigid* than the piece of glass, and to this they largely owe the fact that they remain whole. But the rubber possesses a great advantage over the lead in that it was also *elastic*. It lost its shape only for the space of a second. But the names we are using require a little explanation. Rigid, elastic : what do these qualities really come to ? Let us look at them a little more carefully, for their importance in the history of bridges cannot easily be overrated.

§ 3

We have already divided the structure of the bridge into several parts : the pier, the arch, the roadway. A unit of structure, composed of one pier and one arch (or two half-arches), is not composed of one solid piece of material : a further subdivision is clearly invited, this time into units of

ELVET BRIDGE, DURHAM

material. The units of material are the pieces of stone or brick-clay of which the larger units are built up. These in their turn are composed of smaller particles; further than this we need not go. Each of these units is a particular study in itself: the particles are the business of the physicist, the unit of material is that of the quarryman or clayworker, while the structural unit is the concern of the architect and mason. The division, it will presently be seen, is by no means a gratuitous one. Just such a division is everywhere observed in biological science, where the cell forms the subject of cytology, the organic tissue that of histology, the organs themselves constituting the province of anatomy.

Now to form a clear idea of the various kinds of strength one must imagine our unit of material made up of its particles. Its integrity depends on two things: two conditions must be fulfilled by the particles if the larger whole is to remain intact. They must not, in the first instance, let go of one another, or the larger piece will be *shattered*. But they may still cling together and yet move past one another, shift their position with regard to one another. If they do this the piece will not be shattered, it will become *distorted*. Shattering or distortion, both are the product of the selfsame force, the force that tries to destroy the material. But we may reasonably distinguish two separate kinds of strength whereby these accidents are averted.

First, the molecules resist *movement*, they struggle to avoid a change of place. This tendency towards immobility is productive of a quality in the material which physicists have called elasticity. Now we are not here examining the relation between elasticity and permanence, and we must content ourselves with glancing at the effect of this property as manifested here and now. This effect is clear. Elasticity has nothing to do with hardness or softness. It is often confused

with hardness, but it is by no means the same thing. Let us imagine two substances, one hard and one soft, and watch the particles as they are affected by the pressure of a similar load. The particles of the soft substance will shift considerably : they will run a long way. Those of the hard substance will oppose a more vigorous resistance and will be moved to a much smaller distance. Their resistance may be more vigorous, but is it more effective than that of the others ? Remove the load, and both groups of particles race back to assume the place they originally took up. The pieces look as though nothing has happened to them. They are indeed equally elastic, their strength is the same ; but the particles of the one are animated by the strength of the tortoise, the other's by the strength of the hare. The one relies on force, the other on agility. The one, in other words, is rigid, the other yielding.

Elasticity, therefore, has assumed a dual guise, but it has always been essentially the same kind of strength. Its purpose has been to oppose, not the momentary motion of the particles, but their lasting *displacement*. At one time it allows the motion to take place in a greater measure than at another. Its intensity of action may be high or low, but at all times it watches that the motion shall not inflict permanent injury. Let us suppose that it has failed to do so. We may again take up our piece of lead flattened with a hammer. It still possesses strength : it still has some measure of rigidity. But whatever elasticity it once possessed has gone out of it. Its particles have not only moved past one another : they have become permanently displaced. The next thing that will happen is their *separation*. The piece of lead will be fractured. Now there is still a kind of strength labouring to avert this final catastrophe. One kind of strength has gone : the strength that repairs whatever injury has for a while been

inflicted, the living, restorative kind, the recuperative kind, of strength. Has not a famous scientist given his treatise on elasticity the title of *De Potentia Restitutiva?* The active part of the strength is gone, but there is still a passive kind that remains. The particles have shifted, and shifted irremediably, but they still adhere together. Elasticity has gone : *cohesion* remains at its post.

Let us see how the combination of these two qualities affect a material. Glass, for example, is broken before it can be distorted, that is to say that its cohesion breaks down before its elasticity has been visibly overcome. Such substances are called brittle. In lead the elasticity is destroyed long before the cohesion threatens to fail ; once the lead has been distorted you still have a great amount of cohesion to overcome before you can bring about a fracture. Lead, therefore, is said to be ductile. Clearly the characteristics of lead and glass are the two characteristics which a bridge must before all else eschew. It must not be what we call brittle, that is to say that its cohesion must not be more vulnerable than its elasticity. Elasticity can take care of itself, but cohesion is only fit to constitute the rearguard in this battle against disintegration. It must not be made to bear the brunt of the attack, for it cannot repair such damage as it may suffer : every inch it yields brings the dissolution of the material nearer than it was before. But neither must our bridge be ductile. It must be amply provided with recuperative power. Once it has become irremediably distorted it may as well fall. And we have already seen that this elasticity must be of a particular kind. Unless there is great abundance of strength it must be the *yielding* kind of elasticity. It cannot afford to resist with a too high intensity, for in this there is danger. It must be frugal of its own energy, and not render the attack made upon it more violent by its stubbornness.

These, then, are the qualities which experience will have taught the mediæval bridge-builder to pursue. Let us see how his handiwork betrays its possession of them.

§ 4

To yield, to spring back, this it is that the mediæval bridge has to do, the mediæval bridge in which human skill and human resources are still by no means unlimited, but must, as they are, do the best they can. The two functions are complementary ; they are not the same. They will therefore be performed separately, and, we may expect, by different parts of the bridge. The part which is designed to facilitate the yielding is the free extradossed arch, while the heavily loaded spandril provides the necessary recuperative power.

The arch proper, that is to say the rounded structure divested of the masonry upon which the level roadway is built, is of course a ring of stone or brick. The inside face, technically named (as architect readers will forgive me for recalling) the intrados, presents a smooth and rounded face. Does the outer face or extrados of this ring do the same ? Well, everybody knows the value of bonding, as it is called, in any structure composed of separate units of material. We know that a wall whose stones are not bonded together—do not, that is, each come forward and press upon the next this way and that—will be easily demolished, will lack cohesion, in other words, and elasticity too, since cohesion will often be the first to suffer defeat. The bonding pulls the wall together, it stiffens it. But our bridge-arch must not be stiff, it must yield. It is therefore not bonded into the surrounding masonry. The stones of which the arch is composed do not project and mingle their extremities with the continuous

stones. The extrados, in brief, is finished smoothly and roundly just like the intrados. It is continuous ; it is a proper extrados. The arch is free, a finite, independent thing ; free to swing backwards and forwards without injuring its parts, or the neighbouring parts, and all the more free if all its stones are of equal depth, its thickness constant, its outer and inner faces parallel.

But possessing this freedom it must not be permitted to abuse it. Its laxness must be balanced by a corresponding amount of elasticity. The elasticity must be slow-moving, of low intensity, but it must be there, forever watchful, forever dependable. Most people have felt a bridge-arch swinging under the pressure of a moving vehicle. It swings out of its true shape and returns to it again. What exactly is this movement that is set up in a bridge-arch by a swiftly moving load ? As it rolls over one side of the arch the load will press this side down, it will try to flatten it out. But it cannot do this without causing the opposite half of the arch to rise up in precisely the same measure. The two movements are as inseparable as the contrary movements of a pair of scales. An arch that is flattened out is at the same time shortened, and stone being itself an unyielding substance a shortening at one point cannot be prevented from producing a corresponding elongation at another. No sooner has the load reached the middle of the arch than its pressure tends to raise up not one side of the curve but both at once.

Its downward pressure, however, is throughout translated into an upward pressure of the arch-stones that are furthest removed from it. To resist this upward pressure, to weigh down the bulging arch-ring and keep its stones in their place, this is the task of the vast bulk of masonry that, under the name of spandril, is imposed on the arch-ring of the mediæval bridge. Later builders might think this great mass of stone

superfluous, and construct their spandrils with great hollow spaces inside them, but not so the mediæval builder. The more weight, the more constant and unshifting weight, he could lay upon his flexible arch, the more elasticity it would possess, the greater would be its recuperative power. Now one or two reasons for building pointed arches have already been given, and here is another of perhaps even greater consequence. The taller the arch is in relation to its width, the greater the height—and consequently the mass—of its spandril masonry will be.

One question may perhaps be asked by the non-architectural reader, a very natural one. Masonry is built—is, at any rate, *usually* built—in mortar. Yet in the preceding pages it has been spoken of as a moving, swinging thing, its parts have been described as gliding past one another and gliding back again. Is it not the purpose of this mortar to cause these parts to *adhere*, to make the bridge, in fact, rigid ? And if this is what the mortar does, how are such movements possible, and if they occur must they not bring about the disruption of the fabric ? The answer is that it is no doubt the function of mortar to cause the stones to adhere, but this is by far the least important of its several functions. Whether the stones in a bridge adhere together does not very much matter, but it is exceedingly important that a stone should bear its burden over the whole of its surface and not have it concentrated in one small spot. Yet this may very well be the effect of a slight protuberance in the stone or in that which lies on the top of it. The first duty of mortar is to smooth out any such inequalities—to fill those slight hollows, to do away with those minute ridges and bosses, which would render the pressure unequal and increase it in the measure of its inequality.

In this argument we have looked upon the load to which a

bridge is subjected as indeed moving, but moving at a slow and steady rate, and striking the arch once only as it comes into contact with it. We shall find the importance of the elastic properties just examined to be still greater when that impact is regularly repeated : when, in a word, it assumes the quality of a vibration. Its effects, as every one knows, are then intensified many times. Whether it be a troop of soldiers marching in step (a kind of vibratory load that has caused many a bridge to collapse), or the impact of a horse's hoofs, or the even more persistent disturbance caused by fast and heavy motor traffic, its disintegrating effect will be out of all proportion to its mass. The danger to St. Paul's Cathedral has lately led to such frequent discussion of the destructive vibration set up by our new types of omnibus in the neighbouring streets that only a bare reference to the matter will here be necessary. This problem of vibration and its effects is one which will have to be solved if modern traffic is to be allowed to grow yet more in bulk and speed at its present rate ; where, however, a structure has to resist not only the communicated vibration of a vehicle moving beside it, but, as in a bridge, the initial impact and continued vibratory movement of the whole of its load, it will be seen to assume far other dimensions. How admirably it was solved by our early bridge-builders in the loaded extradossed arch we may conclude from the rare stability of the mediæval bridge under burdens which could not have been imagined by its constructors.

§ 5

The arch must yield and must spring back. Continuous and unvarying movement in response to the movement of the load is the condition without which it cannot survive.

What of the pier upon which it reposes? Does movement constitute the same salutary influence here that it does in the arch? Let us go back to the natural circumstances into which the pier must fit itself, and consider the first of these, the river-bed upon which it has to secure a permanent foothold. Only in the most favoured place is this bed made of an unyielding substance such as rock: most often it will give way, and all the bridge-builder can do is to cause it to give way as little as possible by pressing upon it broadly and evenly. It will be realized that if the pier is allowed to oscillate together with the arch his object will be at once defeated. No matter how broad and even your base, if it moves this way and that it will press upon the soil now here, now there: its whole pressure will at any one moment be concentrated towards the direction in which it happens to swing. Like the horse beating its hoofs in a quicksand it will slowly but irresistibly cause itself to be swallowed up. If the pier is to achieve permanence it must be as rigid as the arch is flexible, for its bulk is sustained by a flexible substance which does not possess the recuperative power conferred upon the arch by the loaded spandril. Nor is there any such element which extends a corresponding benefit to the pier itself. There is no agency at work to make the pier elastic. Its safety is in volume, and also in a rigid immobility.

Now the oscillatory movement of the arch is not the only stress against which the pier has to harden itself. I may be thought guilty of platitude when I remark that all the arches of a mediæval bridge are not built at once; it will, however, be found in another chapter what significance this plain fact really holds. Meanwhile let us see what is its effect upon the construction of the pier. If one arch at a time is built the thrust of this arch against the pier will not be met by the opposing thrust of the arch on the other side. There will,

BRIDGE OF BOATS, AND MOSQUE
OF SELIM, CONSTANTINOPLE

for some time after the first arch has been put up, be *no* arch on the other side of the pier. The pier must therefore be able to resist within its own substance the sideways thrust of this one arch ; it must, that is to say, provide the necessary abutment whereby the arch may be maintained in its position. A stable foundation, a secure abutment, both ends are attained by the same means, both make it equally desirable that the pier should assume the greatest possible breadth. But the necessity for providing every arch with separate abutment affects not the structure of the pier only but the form of the arch too, and this reaction we must be careful not to overlook.

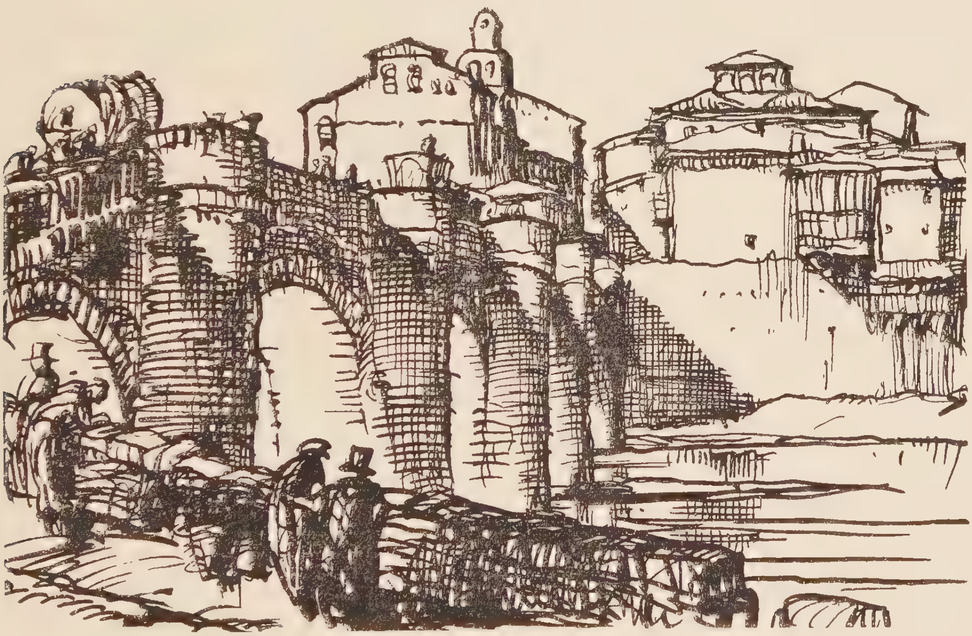
Everybody knows that if a weight be suspended from the middle of a slack wire, this weight will cause the wire to pull at its fastenings with much less force than if the wire were tightly stretched. The slack wire forms a tall triangle, the taut wire a flat one, and what is true of these triangles is also true of arches of corresponding proportions. A tall arch is much less apt to overturn its piers than a flat one bearing the same burden across the same width of span. And we have seen that of all arches other than the semicircular none are so easy to construct as those consisting of two segments of a circle joined together, and forming a pointed arch. A pointed arch is, of course, generally far taller than a semicircular arch of the same span, and to construct an unbroken curve of the same proportions was, for reasons which have been given, not to be thought of. It is probable that among the various advantages of the tall pointed arch there is none of such value as the smallness of its lateral thrust.

Freedom of movement for the arch, but a freedom checked by the recuperative power of the spandril : this is one side of our picture. On the other side we note that the movement of which the arch is capable must be confined to the arch. The arch must be so formed that its oscillations are not transmitted

to the neighbouring parts of the bridge ; the pier in its turn must withstand whatever of this movement may threaten to disturb its equipoise. At this stage our inquiry into the manner in which the forms of the early bridges answer to the pressure of the load may be concluded. The picture we have set out to draw is as complete as it needs to be, and for each of the features composing the bridge a variety of justifications have been adduced. Its behaviour has been disclosed, and its peculiar structure has been shown to arise inevitably from this behaviour. The origin of all forms, the essence of morphogenesis, we are told by biologists, is sensitiveness, a quality which is at its highest in the earlier periods of life. The bridge we have been studying is the early bridge, and therefore the most sensitive, and it follows that in this bridge the influence of external stimuli will be most strongly manifest. Whatever changes we shall afterwards observe will not be attributable to these, for as a civilization advances its physical sensitiveness grows less and less, and as bridge succeeds bridge material conditions and functional needs will control its growth in a constantly decreasing measure. What other forces are then to assume this control will form the subject of another chapter.

The present one would, however, be incomplete without some more precise definition of the sense in which the word *early* is here used. May it be taken to apply to the bridge made out of twisted vegetable stems which the American native flings across a chasm, equipped perhaps with a floor of light wooden planking ? Is a single log of wood, a single slab of stone, laid across a gully by accident of nature or human design, an *early* bridge in our sense of the word ? The answer is that words such as *early* and *late* imply a continuous temporal series, a sequence of things and events, in which these concepts assume a definite relation to one another. The bridge to

which we apply such terms must therefore be one belonging to one of those protracted phases of collective human existence that we call a civilization. It is from its place in this civilization that it derives the name of *early* or *late* ; we have no other means of comparison than this. The anthropological bridge, one of the scanty marks that primeval man leaves of his passage through the wilderness, does not stand in any particular relation to such a sequence, it represents no stage in a history of human endeavour. It may have been built at any time by anyone wishing to establish a communication for a month or two before continuing his journey to some other place. It is a stillborn thing, and must remain outside the scope of our purview. The bridge with which we are concerned is the bridge that develops simultaneously with the civilization



of which it forms a part, composed, like that civilization, of numberless individuals that follow without remission, yet withal presenting those steadfast characteristics that betray a continuous identity, as well as those others whose chequered flow are the phases of a continuous life.

CHAPTER III

§ I

THE bridge is a composite structure, an organism. Like all organisms it grows in obedience to a dual law: the law which springs from its own nature and function, and that which is summed up in the familiar word *environment*. Internal law and external, impulse and circumstance, these are the two forces which between them decide what forms the bridge is to assume. The external law has been watched at work in the first of these chapters, while in the second we concluded that the internal impulse depended on two things, strength and duration. Those were the conditions imposed by nature; these are the conditions imposed by man. The condition of strength has been investigated; let us now take up the other, and seek how the degree of permanence required of a bridge affects the evolution of its forms.

The first question that rises to our lips is, What is meant

by permanence? Wherein does it, as an idea, as a purpose in building, exhibit itself? Is not the temporary, its opposite, rather a fortuitous condition of the material, and do we not give to all that we make the highest degree of permanence of which we are capable? Only when this question has been answered is it possible to inquire how the quality of permanence is achieved, and what are the visible signs of it and of its absence. Now it will be remembered that in examining the concept of strength we began by asking by what this strength was measured. It was measured, we found, by the amount of the load and by its motion. Once these things were known the task of the bridge became defined: thus much, and not, as a rule, more, it was required to do. How shall we define this other object of durability? By what may this object be measured? What is the duration with which we must compare the duration of the bridge? Clearly this standard is set by the process to which the bridge is subservient.

Let me illustrate this. An exhibition is to be held, we will say, for a period of six months. The buildings erected for the purpose of this exhibition are designed for a process of six months' duration, and this period will be the standard whereby the durability of the buildings are measured. Most people order a new suit for summer and winter. This is the standard—a semestrial one—of durability in clothing. The period is the *average* period: accidental wealth on the one hand, sudden penury on the other, will bring about their respective aberrations; nor does our rule account for clothes answering ceremonial purposes as distinct from those intended for current use. None of these exceptions can, however, invalidate our standard. The duration of the process it is that fixes the duration of the object that is to enter into it.

To what process is the bridge subservient? Not, like human clothing, to the warm or the wintry season. Not

even, like the human body, to the individual human life. The bridge is not an accessory to the life of the individual, but to the life of a civilization. Human society it is that requires the bridge as well as the road of which it forms a part ; human society creates it, and for this it has to endure. The standard of permanence in architecture is the length of life of a human civilization. Sir Flinders Petrie has estimated this for us at roughly a dozen centuries, and has given us a brilliant outline of those civilizations that are known to us to-day. Their length varies just as the length of an individual life or the length of a summer vary, but it may be that a fixed equinoctial average exists which we shall probably never know. Still, the rough estimate made by Sir Flinders is sufficient for our present purpose, for it will immediately be observed that the period of time enunciated in his survey is one for which very few works of architecture (if any at all) are able to endure.

The observation is important. The measurable load which, animated by a given movement, we saw imposed upon the bridge, was provided for in the structural organization of the piers and arches. So much to carry : so much to carry it : the terms of the equation were fully known, and answered one another clearly and precisely. The duration required of the bridge is to be measured only by the most learned and courageous of historians, and when it is thus measured it is found to be beyond the capacity of most of our bridges. The standard of duration is unattainable and often unknown : it is not so much a standard as an ideal. It cannot be complied with, it can only be striven towards. It cannot be attained, only approached. However much we exert ourselves we shall still be far from achieving our purpose. It will be seen that there are two aspects to this pursuit of an ideal. First, we are aware that there is no limit to the exertion that we are

called upon to put forth. The only such limit is within ourselves. We must reach as far as we possibly can, with the utmost exertion of which we are capable. There is no external condition which will at a certain moment be fulfilled and cry, Enough! Hence, in the second place, we shall be continually aware that however hard we strive we are still short of our object, that the best we can do is as nothing to what we are required to do. Both these aspects are exhibited in the permanent bridge, and only when the two are present together has the bridge earned the right to that name. The first is shown in the fact that the utmost use is made of all the means whereby the bridge may achieve the greatest durability. The second may be seen in the organization of the structure, which is so contrived that the recognized inadequacy of the means shall be transcended in the life and the strength of the product.

§ 2

The life of a civilization has been referred to, but we have seen that it is a quantity known only to a few people interested in historical speculation, not to those who are responsible for the building of our bridges. Nor could the knowledge of an unattainable object be of any assistance to these in their work. They know the direction in which the object should be sought, but the object itself is as much beyond their knowledge as it is beyond their reach. This makes no difference to their labours. The object is merely turned into a purpose, the knowledge into a faith. The faith is in the continuity of human endeavour; the purpose is permanence. Perhaps we have now come within sight of a definition of this word *permanence*. Hitherto we have spoken of permanence and strength as two similar qualities, and it may have

been inferred that just as there were degrees of strength, so there were degrees of permanence, varying with the demands made upon the structure by the human society to whose use it is dedicated. This view is now proved erroneous. There are indeed degrees of permanence in structures, but since the standard of permanence is immeasurably remote, we may recognize, in addition, an absolute quality of permanence that admits of no degrees. A bridge (we may say) is either permanent or it is not: it is, that means to say, either permanent or temporary. It was acknowledged that most people feel the irreducible disparateness of these two attributes, at the same time being most often unable to draw the line between the one and the other with any degree of accuracy. The foregoing arguments will at once remove any such disability from our minds. It is now clear that the permanent bridge is the bridge in which the material employed as well as its structural arrangement are calculated, first, to ensure the greatest possible durability, and secondly to provide the means whereby this durability may be extended as soon as failure threatens. The temporary bridge is the bridge whose original length of life is not as great as it could under the circumstances be made, and cannot, owing to the peculiar structure of the bridge, afterwards be extended.

Now it was remarked that permanence was the product of a faith in the continuity of society, and it may therefore be concluded that temporary construction owes its origin to the extinction of this faith. To this rule there is an important exception to which attention will be drawn in the proper place. Meanwhile it is the quality of permanence which must here concern us, and now that we know not only what it is, but also what it is not, we may cast a glance at the means whereby it is attained. Before doing this, however, it will be instructive if we consider for a while a special reason for permanence

in bridge-building. If a strong belief in the continuity of civilization is abroad it will be desirable, it is true, that all bridges and other structures answering a social, not an individual, need should achieve the utmost permanence. To all bridges it is granted to serve the civilization to which they belong, and to serve it, if they choose, so long as that civilization shall endure. But not all bridges are permitted to draw the elements of this civilization towards themselves with an ineluctible power, an attraction more than magnetic : to play, in fact, themselves a creative rôle. Not all bridges are predestined to become the foci of great communities of men : foci of quite incalculable importance. Nor is it possible to predict which bridge is to be raised to such eminence and which will have to remain content with its humbler office. The wind bloweth where it listeth, and at any time a bridge may be chosen for this most glorious of all tasks, the task of nation-builder. Such a bridge has been described by Mr. Hilaire Belloc as a *nodal bridge*.

A nodal bridge occurs at the crossing of a waterway of prime importance by a roadway equally important. Most often it is the first bridge, the bridge by which sea-borne craft is arrested as it sails inland upon the flowing tide. A little reflection will convince us why this must be so. A waterway is really of prime importance only in its tidal reaches, and that but so far as it is properly navigable by sea-going ships. Here alone is it able to equal a great main road in volume of traffic : here alone will this road combine with it to form a true nodal point. Here the bridge, ostensibly built, like all the other bridges of the world, to span the void, and carry men and horses across safely and without interruption, will assume this new rôle, drawing to itself from far and wide those currents of people and merchandise which it had formerly been its function to help scatter across the land. Here you

may visualize, if you will, long before the bridge came into existence, a fount of centripetal energy, unguessed by anyone till the dry way was made to cross the watery, and growing thence from strength to strength, from accretion to accretion, until you have a London, a Paris, a Rome, gloriously crowning the hidden site, gloriously crowning it with the life of a million men.

Thus it will be seen what an admirable word is this *nodal* of Mr. Belloc's. For in the sense in which it is used by him two separate meanings attached to it are brought into play. There is first of all the general meaning, that of a knot, an intersection of many lines, a central point in a complex organization. This meaning may arguably be a looser and somewhat careless one derived from the mathematical connotation, and Mr. Belloc's use of the word may indeed be open to criticism in that it is at once falsified if this mathematical meaning is strictly read into it. A node in mathematics does not occur where a line is crossed by other lines ; it occurs where a curved line crosses *itself*. But the general meaning of the word is, it may be urged, quite well enough established to bear out Mr. Belloc's use of it in describing the *origin* of the nodal bridge. The *effect* of this sort of bridge is conveyed by a connotation of the word which properly belongs to the realm of natural history. For here a node is the point of a vegetable stem from which the leaves spring. The movement now is no longer inward, but outward ; the word, like so many others in our language, has a systole and a diastole, both of which Mr. Belloc has been the first to discriminate and to apply in conjunction.

In this conflict, this embrace, of roadway and waterway I have suggested that not only one but both must be of signal importance. Whether this equality of importance is present or no is not difficult to ascertain. I need only refer to London

itself, where the bridge became the confluence of many roads, and the river a storehouse of the wealth of many nations. Another requisite circumstance, however, would seem to be a similarity of formation of the two banks, and equal opportunities for their development. Now it is, as we have seen, a common thing for a nodal bridge to replace an earlier ferry, and a ferry would naturally be established at a point where the task of embarkation and disembarkation was attended with the least difficulty. At such a point we may expect the banks to possess precisely those characteristics which favour the rise of a nodal bridge. Their height, their shape, their substance, will there attain the closest resemblance. Such a point will not be situated on a curve. Everybody knows how at the bend of a river the difference between its banks tends to become accentuated through the flow of the water, the outer bank of the curve jutting forward above, hollowed out below, and the inner extending its shallows far into the stream by an easy and gradual declivity. It is not, therefore, without interest to note that the site of London Bridge marks the central point of a fairly long reach of the river, perfectly straight, and extending from Wapping to Charing Cross.

Now let us see what happens when the essential condition for the formation of a nodal bridge is not fulfilled. The Scheldt at Antwerp and the Tagus at Toledo are both turned into an acute elbow. The Scheldt is an important means of communication ; its importance is to be gauged by the place occupied by Antwerp among the inland ports of the world. From Antwerp, however, all roads lead eastward ; there is no notable communication across the river, and indeed there need not be, for from the western bank of the Scheldt to the sea is no very great distance. The eastern bank, however, is the gateway to a whole continent. Consequently the town will be found to lie at the meeting-point of the converging lines of

the river ; on the opposite bank there is nothing. Vital as the eastern connections are, therefore, enormous as is the area they command, Antwerp is not placed on what we should call a nodal site : it can never be more than a port, though it may be a port (as indeed it is) of very considerable magnitude. The conditions that may be expected to produce an equal development of both banks, and consequently a continuous line of communication transverse to the waterway, are not here present.

Examine, for an opposite tendency, Toledo. We have the same eastward-pointing elbow in the river, and at the elbow a town. But instead of the populous Scheldt, the ample gateway for whose control much blood has been shed and great sums paid down in ransom, we have a river "destined," according to at least one authority, "to be the chief artery of Spain," but, whether so destined or not, an example of loneliness and tragic desuetude that it would be hard to equal. At each extremity of the bend, however, is an ancient and renowned bridge, each completing a line of substantial communication. The waterway is neglected ; the roadways clearly are not, or there would have been no bridges there. The lines of the river converge in a point outside, those of the road on a point inside, the rounded sweep of the Tagus. The town is situated at the inside point, that is to say in a position which is the exact opposite of that occupied by the town of Antwerp. Nor have these roads been able to infuse into the city in which they meet the abundant life, the industry and the wealth that the Scheldt has brought to Antwerp. Indeed, civilization, as I have already hinted, with all its redoubled energy and its vast inventiveness can never hope to provide a substitute for the magnetic influence of a tidal estuary crossed by a great bridge. It can exploit this power : it can make its effects universally felt : it can use it in the

building up of capitals such as those I have mentioned; it can also spurn and neglect and befoul it, but it cannot create anything to take its place.

Permanence, it will be seen, is an ideal, but it is also something more: the qualification for a higher activity, for a more exalted form of existence. It has to be pursued not only for its own sake but for the sake of the great call that may be sounded no one knows when, a call which it is the noblest function of the bridge to answer, able and ready to carry out its behests till the death of the civilization which it has helped to bring into being.

§ 3

Let us revert to the question of how this permanence is achieved. Here is our bridge, divided into its structural units, its piers and arches. These in their turn are composed of units of material, and it is, we saw, the first condition of permanence that these units shall be of the most permanent material that the builder is able to command. What is a permanent material? Is there a division between permanent and temporary materials similar to that which separates permanent construction from temporary? It will be recalled that the absolute quality of permanence in a structure depended on the presence of a faith, an impulse. A structure in this sense is either permanent or it is temporary. The same cannot be said of a material; here there is no faith by which to apply the crucial test, here no human impulse has entered to set up its own dual world of good and evil. A material may be more permanent or less permanent; there is, properly speaking, no such thing as a temporary material. This is why it was laid down that in the construction of a permanent bridge

CHESTER BRIDGE

it was necessary to use, not a permanent material, but the *most* permanent material within reach. For the English bridge-builder this material is stone, and it follows therefore that most of our permanent bridges have been built of this material. Where stone cannot be had, however, a permanent bridge may be built of the next best material, brick or wood or any other. It must, however, be the most permanent that can be found.

A confusion between the permanence of a material and its strength must here be guarded against. The two qualities are no more identical in the material than they are in the structure. A visit to the British Museum will reveal the existence of innumerable objects of very great permanence but of so little strength that a smart blow with a hammer would shatter them at once. On the other hand, strength without permanence is daily achieved by engineers in all parts of the world. Perhaps Mr. Edison may yet invent some substance which, though of adamantine strength, will automatically disintegrate and reduce itself to powder after a space of, say, two years. I can imagine a good many uses to which the new material would be enthusiastically put. No doubt our motor-cars and battleships would be built of it, for no one is anxious to be seen by his friends in a motor-car as much as two years old, and the time is fast approaching when to wage war with battleships of that age would be to court disaster. Side by side with Mr. Edison's agreeable innovation we should have the limestone and greenstone, the granite and basalt, that Nature holds in her inexhaustible storehouse still. And gold and other substances would still give us a permanence shorn of the great strength that would be exhibited in the new material.

Now a material may be subdivided into its particles, and these once more into molecules, and each of these constituents

are governed by a particular form of permanence. The power whereby the molecules preserve their integrity is called the chemical permanence of the material, while the particles maintain themselves by virtue of what we call its physical permanence. Both are important, both are definite restricting quantities which the bridge-builder cannot by any means evade. They are, in fact, the only quantities that limit his achievement of permanence. They limit it, but not directly, for his achievement is something more than the choice of a material, it also consists in utilizing that material to the greatest advantage, while striving to transcend its inherent defects.

Having chosen a material but slightly subject to chemical change the bridge-builder may still dispose it so as to minimize the likelihood of such a change. Chemical disintegration takes place on the surface of a material, where it comes into contact with the elements of air and water and the substances which these contain in solution. The first way of ensuring the greatest possible chemical permanence of a material is to give it the smallest possible superficial area in relation to its bulk. The less the extent of its vulnerable parts the better it will be able to resist the forces that strive to cast its molecules asunder. Now as a solid increases in size its volume increases more rapidly than its area. The greater, therefore, the solid bulk of masonry in a bridge, the less will be its area in relation to this volume. We have already discovered other reasons for making both the pier and the spandril of the permanent bridge as solid and as voluminous as possible. Here is another and an equally valid one. It may not seem of quite the same importance, but when we come to examine the temporary mode of construction we shall realize what a peril the continually expanding surfaces characteristic of this mode really hold.

§ 4

The connection between permanence and elasticity has already been hinted at. Let us recall what is the scientists' definition of perfect elasticity. It is, they say, the property inherent in a substance which having been distorted under the pressure of a certain force resumes its first shape quickly and completely when the force is removed. They further demand—and this is the important part of the definition—that it shall go on doing this for ever, and always with exactly the same alacrity and the same precision, no matter how often the distortion is inflicted upon it or for how long a period it is maintained. It will be seen that perfect elasticity can only be found in a substance that is eternal, that perfect elasticity represents, indeed, the goal of permanence which to our bridge-builder is invested with such profound significance. It is needless to add that neither is found in any material known to man. Permanence of material is, we know, entirely a matter of degree.

Now stone is not what we should call an elastic substance. Its cohesion, therefore, has to be the more carefully guarded from the dangers that attend the exacting office which it has to perform in a bridge. How the mortar joints are instrumental in protecting each stone from unequal pressures we have already seen. But a greater problem still awaits the bridge-builder: how to contrive out of an inelastic material a structure that shall be elastic. The extradossed arch provides the solution to this problem. The extradossed arch, however, is a moving thing, and there is danger that the material units may be shattered, not indeed by the pressure of the load only, but by the movement of the arch which is so useful in maintaining these units in their proper position. Here again the mortar

provides just the protection that is wanted, for while the mortar is still but imperfectly hardened the bridge will be in use, the movements of the arch will have begun, and the mortar will yield and gradually be moulded into a shape which enables the movements to continue without exposing the stones to injury.

Thus much for the elasticity of the structural unit : what of its other kind of strength, its cohesion ? The cohesion of the structural unit is not so dangerously threatened as the cohesion of the stone, which has no elasticity to defend it, but it must still be maintained with the utmost care. Just as the bridge-builder took pains to endow his arch with an elasticity that was not to be found in the individual units of which it was made up, so he will also strive to give the arch and pier a cohesion that is greater than that of their materials. His mode of construction will be such that when the arch is subjected to a load its material units are secured more closely together, and are also compressed within their own substance. The load, therefore, sets up a double reaction in the permanent bridge. First, it causes its arch to yield and thus suscitates the sleeping forces of elasticity which protect the arch against disruption. Secondly, it actually increases the cohesion of the structural units, so that the bridge is stronger when the load is upon it than when it is in a state of rest. How important this double reaction is may be imagined without difficulty, but the benefit it confers upon the structure will be still more clearly observable when we are examining the temporary bridge.

§ 5

Thus far the principal structural device calculated to impart permanence has been the elastic construction of the arch.

Elasticity connotes, we have seen, a dual property, one of ordinary spatial strength and one of duration. The elasticity achieved in the pointed extradossed arch of the mediæval bridge is one of a high order, for the material units are so disposed that their movement is very unlikely to injure them. Indeed, the decrease and ultimate cessation of the power of elasticity in a substance is always the result of injuries inflicted upon its particles. Sometimes these injuries may be only temporary, and after a period of rest they may be automatically repaired and the lost elasticity restored. Such a temporary loss of strength is usually referred to as elastic fatigue. The loss may, on the other hand, be permanent, and when this happens nothing can render the substance elastic again. It will be realized that the recuperative power which here is absent resides within the particles themselves. When the effects of elastic fatigue are overcome after a period of rest it is because the particles of the material contain within themselves a recreative power which is able to restore their formal and mechanical integrity.

No such recreative power is inherent in the stones of the bridge-arch. Injuries inflicted upon these stones are irreparable, and it is therefore of the utmost importance that they be at all times avoided. The life of the bridge-arch is no longer than the life of its material units, but care may be taken that it shall not be needlessly curtailed by the failure of a unit. Yet we have seen that the ideal of permanence imposed a dual obligation on the bridge-builder. He must not only choose the most enduring material and make the most enduring use he can of that material, he must also reach beyond the life of the material and give his bridge a permanence that is greater than that of its constituent units. It has been shown that the permanence of the arch does not fulfil this condition. It is limited by the permanence of the material units. Where,

then, are we to look for this recreative power ? If the arch-stones are not so constituted as to be able to repair injuries done to the arch, perhaps the construction of the arches themselves will render such repair possible. If the power within the material unit lacks the recreative ability, perhaps it may be found in the power that resides in the structural unit.

What is this power ? It is, of course, the human skill by which the arch was created, just as the power within the material is that to which the material owes its origin. Is the bridge-builder able to restore the strength of a structural unit that has become injured ? He may do so upon one condition. The arch is flexible and elastic ; it is a moving thing. Now you cannot repair a thing that is in motion. The first thing a physician does with a broken bone is to immobilize it : without this precaution the power of recreation inherent in the bone would be greatly hampered in its work. A similar obstacle to repair would indubitably be presented by the movement of the injured member of a bridge. Its movement must be arrested if this repair is to proceed. Communicated movement must be rendered impossible. The flexible arch must therefore be contained within inflexible limits : its motion must be isolated by motionless piers. The pier, fortunately, is so constructed that it will resist the oscillatory movement of the arch, and also, it will be recalled, the outward thrust exerted by it on each side.

There are two reasons, then, why the pier is a broad one in the mediæval bridge. First, it has to secure a firm foothold ; secondly, it has to remain motionless in its place. Proper foundation and proper abutment have, that is to say, to be provided, and for both of these great breadth is necessary. Let us now look at our bridge in its entirety, and note how its parts are related to one another. We have a structure which, as a whole, is rigid, being contained within immovable abutments at

each end. It is, however, composed of a series of structural units which are elastic and responsive to external motion. But each of these units is separate, its motion is isolated from the next unit. This is done by confining the extremities of each of the units between rigid piers. Moreover, these units, which are flexible and elastic, are in their turn composed of material units which are inflexible and inelastic. In the middle of our series we have, it will be seen, an elastic unit : the arch. Above and below this unit we have the inclusive whole and the smaller constituent unit, both of which are rigid : a number of elastic units, each composed of rigid particles, are composed into a rigid whole. What is the secret of this double transformation ? It is, of course, the separateness of the units. If the arch-stones were securely locked into one another and into the surrounding masonry they could never constitute a flexible arch. If the arches were not separated by dividing piers but were linked together like those of our modern bridges they could not, being themselves flexible, together form a rigid whole. Just as the *proportion* of its parts furnishes the most striking evidence of the behaviour of the mediæval bridge with regard to the natural conditions of its site, so the *isolation* of these parts will tell us more than anything else about its reaction to the human purpose for which it was created. In such isolation we may find a convenient name whereby to remember this kind of bridge. We will call it the synthetic bridge.

§ 6

The synthetic or discontinuous way of building is notable for a variety of consequences, but among these the localization of fractures has been found the most significant. By this means alone have the great mediæval bridges of this country

survived to the present day. Nearly all of them bear in their arches evidence of the continual rebuilding to which they were subject. No two arches are alike, no two are of the same period. A bridge like London Bridge was never out of the mason's hands : one or other of the arches was always being rebuilt, year in, year out. An example particularly rich in evidence of this kind exists at Hereford, where the arches represent every phase of English building from the thirteenth century to the nineteenth. This, then, is what was meant when we observed that the bridge which aspired to the quality of permanence must strive to transcend the durability of its material.

The restorative power had, in addition, a special aspect which endeared the synthetic mode of construction to a group of people who were as anxious one moment to build bridges as they were to pull them down the next. I refer of course to those engaged in military operations. Thus it came to pass that the disappearance of the synthetic bridge was rendered much more gradual than it would have been without this military value of the synthetic technique. The age of the Renaissance, as it is called, is remarkable as a turning-point in many departments of life, but in none, perhaps, quite so much as in that of the structural arts and manufactures, where it caused the artificer to be superseded by that creature of a ripe civilization, the engineer. And just as the origin of the engineer is military, so we shall find the changes in bridge design that corresponded with this supersession to be timed by the evolution of military methods and conditions. It is of set purpose that the military aspect of bridges is but slightly touched upon in this essay, for speaking generally its influence upon bridge design is visible only in supplementary structures that have no organic connection with the bridge proper, structures such as towers and gateways, works of ordinary

military architecture just as much as the houses of Old London Bridge and the triumphal arch of the Roman bridge at Rimini are works of ordinary civil architecture. But there are two places in which the development of our methods of warfare and that of bridge design intersect, and where the one exerts a decisive influence upon the other.

Up to the time of the engineer a bridge was indeed a very important object to the military leader, who came to rely in turn upon its weakness and its strength, its power to open a line of communication, to maintain it and to control it, upon the one hand, and, upon the other, its power to rupture this line beyond thought of immediate repair. Briefly we may say that the permanent and the destructible are, in the realm of warfare, coexistent resources between which your commander has the choice, and that this choice will vary precisely with the strength of his position. If he is out to make conquests and to maintain the new provinces in his power he will be driven to make his communications strong and durable; if, we will assume, his object is not to attack but to evade, or even to seek protection (as in the bridge at Babylon of whose wooden platforms we may read in Herodotus) he will be more at his ease with a bridge that can be destroyed in a trice when danger threatens. There is nothing new in this, for we have seen that faith in the continuity of human affairs must always be present where permanence is made a prime object in architecture. Can permanence be achieved side by side with this facility for temporary disablement which is so valuable in mediæval warfare? The synthetic bridge supplies the answer. In the synthetic bridge an injury is localized; it is easily repaired in a permanent fashion, and even more easily in a temporary. And having been repaired with a wooden framework it may be again disabled in a very few minutes. The severing of a line of communication is of course—and

always has been—one of the principal resources of campaigning. In mediæval times a bridge that had been temporarily disabled for military purposes might not be repaired—and there was a severe penalty—without the special permission of the commander of the forces.

§ 7

The recreative power inherent in the synthetic bridge is the means whereby a perishable material is made to serve an imperishable purpose. The sad mortality that o'ersways all earthly substances having been defeated, a civilization may continue to use the structure for as long as it shall be required. Permanence is not a matter of material : it is a human ideal, a human impulse, which decrees that out of the corruptible shall be brought forth the incorruptible. It has been maintained, and will now appear almost obvious, that such an impulse, though it does not depend on the qualities of the material for its achievement, will yet be satisfied with nothing short of the most permanent material that is to be had. If a person dressed in a beautiful new covert-coat were discovered wearing beneath it a shabby and ill-cut jacket, we should say that something was lacking to his sartorial distinction. A similar criticism must be levelled at a permanent structure in which a more perishable material is utilized than was really necessary. Though the human will to continuity is able to triumph over the material and to set its weakness at naught, we should yet say that this will was but imperfectly manifest where the weakness had not, in the first instance, been reduced to its lowest point. A bridge of wood in a country rich in building stones and clayfields would not, no matter how well it was constructed—no matter with what ease, vigour and celerity its parts were one by one recreated—deserve

to be called permanent. The intention to secure permanence would only half be there.

A wooden bridge in a country entirely bereft of building stones may claim to be quite otherwise regarded. But suppose the stones are there, yet exceedingly hard to quarry and, when quarried, awkward to build with. Clearly in such a place the builder would be governed by the comparative magnitude of the two tasks that lay before him. It is, in England, let us say, so much *more* difficult to hew and raise up pieces of stone than it is to fell and cut logs of timber. On the other hand, it is so much *less* difficult to construct a permanent stone bridge and to maintain it in a state of permanence than it is to attain the same object in a wooden one. The increased difficulty of making a permanent structure of wood is, that is to say, more redoubtable than the increased difficulty of finding, transporting and handling the more permanent material. The balance is struck, the lesser evil chosen.

In the country which I have described the reverse would happen. To obtain and work the more permanent material would require a greater effort than to build an enduring bridge out of the less permanent. Fortunately we need not continue to use an imaginary example, for the very condition we are discussing is found to prevail in several places, as, for instance, in Japan. The stones that are to be obtained from the mountainous regions of Japan are all of the hardest known to us. Limestones and sandstones, the favourite materials of the European mason, exist in the smallest quantities only ; their place is taken by granite, porphyry, and a variety of volcanic rocks. These stones are not stratified, that is to say they are not, like ours, made up of parallel layers which confer upon it a kind of strength eminently suitable for structural purposes. On the other hand, the forests of Japan, which cover an astonishing proportion of the area of the islands, are

blessed with a greater diversity of trees than may be seen in any other country in the world. The choice of timber for building, though the product may be destined to endure for centuries, here comes very naturally. Two interesting observations are to be made upon the way in which permanent bridges are obtained by the use of such a perishable material as wood.

What is the effect of recreation upon the visual appearance of a European stone bridge? Always a slow and gradual process—the more strongly the bridge is built the slower its rate of decay and recreation—it yet is able to alter this aspect a good deal. Each successive phase will bear a character that is clearly distinguishable from that of its predecessors. No matter how disparate the phases, however, they will not be able to alter the bridge's formal identity. The same is true of the process of recreation which is continually going on in the tissues of the human body: in its slow rate lies the guarantee that our physical identity will continue unaltered and unobscured. The human body is subject to a thousand variations of mood, of temperature (to name only two kinds), and if the rate of recreation were comparable to the rate at which these changes occur it could not but be affected by one or other of these. Its greater length of cycle, its greater amplitude, give the recreative process a stability and a balance upon which the sameness of its results depends. It would be quite otherwise were the rate of recreation hastened so as no longer to embrace a large number of the lesser changes. In bridges, too, we may expect to see the continuous formal identity threatened by a quickening of the recreative process.

Let me explain this danger from another angle of view. The high rate of decay of a short-lived material, and the consequent high rate of recreation of a permanent bridge constructed of such a material, are the causes of a phenomenon

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whose derivation will come before us in the following chapter, but which has now to be briefly mentioned. It is the corresponding diminution of the mass of a bridge. Just as wood is possessed of a smaller specific mass than stone, so a wooden system of construction will employ a smaller proportion of material than a more permanent one. The volume of solid stone in the mediæval bridge we have been studying is perhaps a thousand times greater than the volume of solid wood in a Japanese wooden bridge. Now it is obvious that the more tightly packed your material, the greater the mass of your structure, the smaller will be your opportunities for variation of structural form. Suppose we are compelled to arrange a certain amount of material into the most compact shape it is possible to devise. No latitude whatever will then be allowed us, for we shall have only one form which will satisfy this requirement—the sphere. Double the room which it is permissible to occupy, and the material may be drawn out and given, among many others, the form of spiral, a vase, a star. Decuple it, and the number of shapes into which it may be worked is increased to an unimaginable extent.

The more lightly constructed our bridge, then, the more tenuous its members, the greater will become the variety of forms which these members may assume. The process of recreation in such a bridge cannot be trusted to take care of itself, the identity of the bridge does not find an automatic safeguard in the nature of its structure and materials. A regulative force must be imposed from without if this identity is to be maintained. Such an agency is at work in Japan, and its effect is so powerful, its success so complete, that before the irruption of Occidental civilization a mediæval wooden bridge of that country, though constructed of a flimsy material, though rebuilt, it may be, several hundred times, preserved its original forms more faithfully than any of our

own more durable structures of stone. How was this rare formal continuity achieved ? What was its secret ? Not a very recondite one, to be sure. The recreated bridge or portion of bridge was always a scrupulous facsimile of the structure whose place it took. Since an approximate sameness was not assured from within, a perfect and unwavering sameness was imposed upon it of set purpose from without.

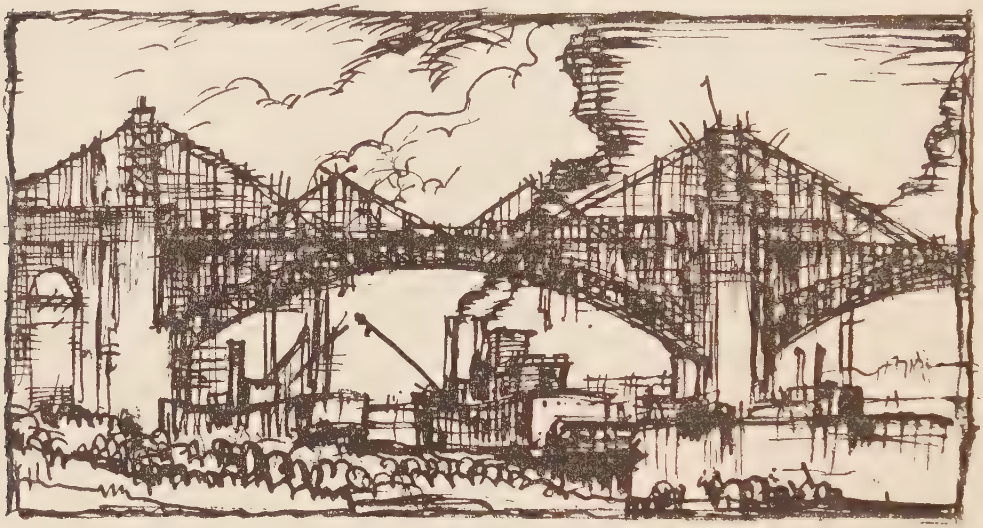
Perfect and unwavering—how, it may be asked, was such a sameness achieved for bridges rebuilt all at once ? Was the design meticulously registered in drawings and measurements, or was it entrusted to the memory ? Neither, if possible, the one nor the other. Drawings and measurements and, *a fortiori*, mnemonic record, were alike insufficient. The old bridge itself must serve as a model, nothing else would do, and to this end the favourite method of rebuilding was chiefly directed. A synthetic bridge, in which one arch was rebuilt at a time, presented no such problems, but for the kind of which we are speaking two alternative sites were provided, and the new bridge was constructed *next* to the old one while this still remained standing.

For either kind of bridge an important condition must be satisfied if this process was to attain its full object, and this leads me to the second important observation which we were to draw from the permanent building technique of Japan. The first was the scrupulous copying of the old bridge or part of a bridge from that very bridge or from a corresponding part still in existence. The second, necessary to the first, is the determined and systematic forestalling of natural decay. If an object is to be copied, this copying must be done before the object has suffered the smallest change, otherwise a discrepancy will occur, and a score of successive rebuildings will multiply the discrepancy by twenty. The signs of decay, therefore, are not awaited. On the contrary, the shortest

average life of the structure is taken as a regular accepted maximum beyond which none may live. It is a common thing for a Japanese wooden bridge or temple to be rebuilt annually, and with the native suspension bridges this is indeed the usual practice. A well-known bridge of this kind which used to be renewed every autumn, until, of course, the Occidental era supervened, is the Tsuri-bashi spanning one arm of the River Fujikawa some miles south of Kajika-zawa. For some substantial structures longer periods are allowed ; thus the Shinto temples at Ise are demolished every twenty years, while the Kintai-kyo bridge at Iwakuni used to have one of its five arches rebuilt at quinquennial intervals, so that once in twenty-five years the whole structure was renewed from end to end.

Decay, however, was not only forestalled in the act of recreation, it was rigorously shunned because of its own intrinsic harmfulness. Once the new bridge or temple erected, the old was quickly and unmercifully swept away. If it were not allowed to suffer injury before the recreation was completed, neither was its gradual downfall tolerated afterwards. No Japanese temple or bridge was allowed to fall to pieces, for thus the spirit of continuity which is at the root of all civilization would have been visibly enfeebled, and the permanence achieved in the new structure would have been given the lie in the outworn condition of the old. This achievement it is that may be observed wherever the flower of civilization has been in the bud, wherever the future has raised a beckoning hand to human endeavour, wherever a human race has aspired to dwell in the House where, as Donne says, there was never heard quarter-clock to strike, never seen minute-glass to turn. It may be observed in all places and at all times, no matter what means are available to bring it about, whether plentiful or scanty, nearby or remote. The means

are never enough ; the triumph is a triumph of the human mind, transcending alike the happiest and the bleakest of circumstances, by what means we are now, I hope, in some measure aware.



CHAPTER IV

§ I

WE live in a dual world of time and space, and in ourselves as well as in the objects surrounding us the changing interplay of these two dimensions may be watched perpetually changing. In the two last chapters we have glanced at some of the signs of this reciprocal action that are exhibited in the bridge. To begin with, the purpose of the bridge was dual, was divided in compliance with the space-time system ; strength was one thing, permanence another, each being made to govern the dimension proper to it. How was this dual purpose achieved ? A combination of material and structure, a definite arrangement of matter, it was from which the bridge sprang into being. Thus it became clear that each of these two things must in its turn answer the double requirement of strength and permanence if the bridge itself

were to exhibit these qualities. Strength and permanence in the organization of the material units, these were the means at the builder's disposal, and he must employ each one of them to the best of his ability if his work were to attain its object. Now the pursuit of strength has already been adequately dealt with. We have seen how a material possessing a strength of one kind is arranged into forms in which quite another kind of strength is produced. These various kinds of strength in either unit have been made to disclose their origin, which lies in the connection between the constituent particles, the reluctance of these to be drawn away from their habitual positions and to be separated from one another. The same has not yet been done for the quality of permanence. The temporal strength of a material or a structure still has to be described in its own terms of time just as the spatial strength was described in terms of space.

Permanence (and this is all that has been said thus far) resides in the power by which a material or structure is able to preserve its forms from disintegration for long periods of time, and, as an extension of this power, that other which enables it to restore or renew such forms with undiminished quickness and effectiveness whenever a failure does occur. When both qualities are present in a high degree the result is permanence. We have seen by what formal peculiarities these qualities are obtained. Permanence has been traced back to its physical manifestations, but its origin has not yet been sought in its own domain. The only incursion into this domain, made at the end of the preceding chapter, showed us that permanence was really a slowness of the ineluctible process of decay. Here, and not till here, we began to speak in terms of measured time, in terms of velocity. It is in suchlike terms that the further examination of the quality of permanence will now have to be taken up. To do so, however,

will be to introduce an idea which has hitherto remained entirely foreign not only to the history of architecture but to that of all the visual arts in which man is engaged. The idea of *tempo* is a commonplace among those who speak of music and poetry, but it has still to be admitted to our discussions of architecture and painting. And yet physical science has already fully and irrevocably acknowledged the influence of velocity upon form : indeed, there are those who see in form nothing except a function, as it is called, of velocity, the fruit of a given velocity and nothing else.

Thus far it will not be necessary for us to go. But while permanence is, as a human attribute, an absolute thing admitting of no degrees, as a natural quality, quantitative, measurable and exhibited in highly diverse degrees, we shall have to concede that it is at bottom a form of velocity. In conceding this we need not be disturbed by the apparent novelty of the idea. Though it is novel in architectural science it is universally admitted in most others. It is, in fact, a notorious truth that the evolution of morphological theory (our subject in these pages) has proceeded separately in each of its subdivisions, and that its truths, which are universally applicable, have passed through one sequence of speculation in the realm of geology, through another in the realm of biology, and so forth, not one of the series being even approximately parallel with another. Thus it need not surprise (and certainly not disquiet) us that a law which is familiar to all students of biology should remain comparatively strange to students of architecture. Its validity, its relevance, are not necessarily discovered on all sides at once, and our lateness on this particular side does not diminish its claim to authority in the smallest degree.

What is this law ? Let us state it as simply as possible, first as it applies to material, and next as it applies (with greater

consequence to us) to structure. All materials grow, stone just as much as wood, and all likewise decay. Now between the rate of growth and the rate of decay there is a close affinity. As the one rises or falls, so the other. The two are not only complementary and contiguous, they not only divide between themselves the whole term of life of an organism: they are so essentially akin that they move to a similar tempo. It is a commonplace that those races which mature quickly also age quickly. It is less of a commonplace, but it is equally true, that a bridge whose rate of growth is high will exhibit a correspondingly high rate of decay. Its permanence, therefore, will be slight, for the degree of permanence is in inverse proportion to the rate of decay. We now see that it stands in a similar relationship to the rate of growth. Increase this rate, and your bridge as well as your material loses in permanence what it gains in speed of construction. Let us take an example among organic substances. Oak grows at a much slower rate than spruce, for it takes three centuries to grow to its full stature: oak, consequently, is the more permanent of these two kinds of wood. Arrest its growth, snatch it from the living processes that were raising its stature and swelling its girth, and what happens? The place of growth is taken by decay, but where there was a slower growth you will find a slower decay.

Let us recall what were the visible signs of permanence in the bridge, and see in how far they are present in the material also. They were first the shortness, and secondly the density, of the structural units. The arches were of small span, and the volume of masonry in relation to this span was considerable. Similar characteristics are to be observed in the more permanent kind of wood when we compare it with the less permanent. The pieces of oak and spruce are composed of structural units which we call fibres, and among these also

there occurs the same dual change of shape and of substance, the same product of morphological and histological differentiation, that was found expressive of permanence in bridges. The fibres of the oak are shorter, and they are also of greater density, than those in spruce. There are more lengths of fibre to a given length of wood, and there are more cells to a given length of fibre. Such a differentiation corresponds closely with that which was found in the bridge. It will be seen from this that the structures built by man are subject to a law which governs all growing things. The law is a law of growth merely, and it is no animadversion upon the dignity of the human intellect, or upon the power exerted by it over the external world, to recognize that such laws operate even within the range of that power. The fact that a thing is made by human hands does not place it beyond the common order of nature.

Our conception of the quality of permanence has gained considerably in sharpness now that we are aware of the meaning of permanence and of its origin. Even as we sow, so shall we reap, and as we build so shall we afterwards enjoy. But in considering this great truth it is more important than ever that we should bear in mind the division of structure into material, a division which may be repeated again and again, since all material is constructed of some more primitive material, and so forth until we reach the smallest division recognized to-day by physical science, a unit of matter whose place will probably be taken to-morrow by another and smaller unit. On the other hand, the bridge itself may be looked upon as part of that larger structure which is a human civilization. What it behoves us to remember, then, is that the rate of decay of a thing is proportionate to the rate of growth of that thing, not necessarily to the rate of growth of the substance whereof it is made. This substance has been constructed at a rate

which fixes for it a rate of decay of its own, and where this rate is high its effect may yet be overcome in the larger structure by means of a highly developed power of recreation.

§ 2

The rate of growth has two aspects, corresponding to the division and subdivision of the bridge into structural and material units. The structural unit may be long or short, the material units may be separated by a greater or smaller proportion of empty space within the structural unit. The greater length and greater tenuity of the structural unit is, it has been asserted, the result of an increase in the rate of growth. The manner in which this comes about requires a closer scrutiny.

It may at first sight appear entirely unnecessary that a change of velocity should produce a corresponding change of form. Let us take the example of a man walking, an example to which we shall later have to revert. The man is animated by an idea of continuous motion, but his body is so constructed that this ideal motion is broken up into a motion of the limbs that is no longer continuous, but proceeds by recurrent intervals which we call steps. The speed of the man now ceases to be a simple and indivisible entity. It will readily be seen that it is a combination of two things, being conditioned first by the velocity with which his legs swing at his hip-joints, and secondly by the length of his legs. His velocity, in other words, is a product of the length and the quickness of his steps. Now let us watch this man and observe what happens when his rate of progress alters. Suppose he wishes to move twice as fast as he has hitherto been moving. There are two ways in which he may do this. He may accelerate

the swinging of his legs or he may increase their length. Let the reader forbear to smile at this second prospect, for it is one which is less impossible than may at first appear. The man, in order to increase his own speed, in order, that is, to change this speed, has the choice between two changes : one of velocity, one of form. We know which is the easier. He will start into a run, he will set his legs swinging more rapidly in their sockets. If he solves the difficulty in this way no change of form will be necessary, while if a change of form be impossible (as it is impossible to animals, for example) a change of velocity will provide the only solution.

Now imagine the reverse to be done. Suppose our walker is disinclined, or, from the constitution of his body, strictly precluded, from accelerating the swinging of his legs. He will then be compelled, in order to increase his own speed of motion, to resort to a change not of speed but of form. He may, that is to say, attach to his feet a pair of stilts, since his own legs were measured for him by his Maker ; or if he will mount a bicycle he may increase his effective length of leg yet more considerably. By imparting to his legs precisely the same speed of motion a man using a pair of stilts may advance twice as fast as a man walking on the ground, while a cyclist may, if he choose, increase the speed fourfold or even more. It is interesting to note that where still higher speed is required, as in cycle-track racing, this speed is obtained not by an increased speed of motion of the limbs, but by means of a higher gearing, that is to say an increase in the length of leg —a *formal* change once more, not one of velocity. I might give a number of further examples, such as that of a man baling water out of a boat, which he might do more quickly either by quickening his movements or by using a larger bucket ; but the point has, I believe, already been made sufficiently clear.

Now the necessity of a formal change in the bridge will be demonstrated if we find that it is not able to accelerate its growth by the alternative method. Let us see what the choice really means. A bridge is composed of a series of structural units, and it may either increase the rate of growth of these units, or it may, by increasing their length, decrease their number, just as the longer leg and the larger bucket will each require a smaller number of movements than the shorter and lesser. Is it possible to increase the rate of growth of a structural unit ? If it is possible, and possible to the extent required, then no change of form will be necessary. The rate of movement of the human limb may be increased, but only within a certain limit, and it is when we wish to transcend this limit, to exceed the velocity of the runner, that the bicycle commends itself to us. Can we increase the rate of growth of a bridge-arch to the degree required, if we can increase it at all ?

The growth of this arch is the fruit of the simple and familiar process of laying one stone on top of another. I shall put no strain on the reader's credulity in stating that the speed of this process cannot be varied to any significant degree. We hear a great deal to-day about the restriction of output, but the restriction can, where a full day's work is done, be of but little consequence. The laying of one stone on another is not likely to be done in much less time than it took the builder of five thousand years ago, provided, of course, the stones be not too large for a pair of human hands to move. The movements of the mason, derived from strength of sinew, quickness of eye, pressure of pulse, observe a rhythm that is constant from age to age, unaffected by such minor variations as may sometimes be observed in the individual. These are things that will never change ; and as they are the elements upon which the rate of growth of the masonry depends, it

TWO AQUEDUCTS, SYMANA, TURKEY

may be said that this rate of growth is, at bottom, constant also. A formal differentiation is clearly necessary if the bridge is to grow more quickly.

It is interesting to note a second fixed quantity, a second limitation that restricts the acceleration of the rate of growth of individual units. A structural unit is composed, it will be said, of so much solid masonry, and so much empty space in the arch-opening: could not the first be decreased in proportion to the second, thus making the arch lighter without lengthening its span? It may be thought, and not without reason, that if the rate of growth of the masonry is fixed, then an arch may be constructed more quickly if less solid masonry be used in its composition. There are two reasons why this is not possible. The first is that the building of one of the arches of a synthetic bridge always requires just the same space of time, no matter what its span. Building, as everybody knows, is a seasonal occupation like all those fundamental activities in which man is brought face to face with Nature, his processes being regulated by her processes, his tempo by her tempo. There is (I am speaking of the pre-industrial age) a fixed time for the building of one arch, and that is one year: neither more nor less. Pier and arch are begun in the spring and finished in the autumn, and the next is not begun until the spring comes round again. If a month or two be saved, therefore, in the building of an arch, the saving will not benefit the bridge, which will be built none the sooner because of it. The second reason why the bridge-arch does not preserve the same small width of span while diminishing its volume of solid masonry lies in the evolution of the human society of which the bridge forms a part. About this evolution nothing need be said at this stage, but I may remind the reader of a statement already made, that one of its effects was to diminish the sensitiveness of the bridge. And as the

chief characteristics of the mediæval bridge, its broad pier, its narrow, pointed arch, its great bulk of spandril—the shortness and density, in brief, of its structural units—arose directly from its great sensitiveness, it will be seen that with the decrease of this sensitiveness the forms lose their principal justification.

Let us now observe the precise nature of the formal change whereby the bridge is able to accelerate its rate of growth. The rate of growth of the solid masonry is constant, and so is that of the structural unit. The solution is clear. If every arch takes one year to build, the bridge can only hasten its own building by reducing its number of arches. And since the arches must, whether wide or narrow, consist of the same volume of solid stone, this volume will now extend over a greater length. Longer arches, and a smaller proportion of masonry to the length of arch: such are the signs of accelerated growth, a departure, of course, from the chief characteristics of the permanent bridge, which were found to exhibit so close an analogy with those of the more permanent timbers. The signs are so constant, the morphological and histological differentiation so faithfully representative of the increasing rate of growth, that a well-known archæologist, Mr. Harry Inglis of Edinburgh, has, in a series of fascinating papers on bridges read before The Society of Antiquarians of Scotland, dated a number of bridges from no other evidence than the width of their spans. And not only this, but upon the same evidence he proceeds to demolish more than one traditional date, hitherto accepted by historians everywhere.

This independent testimony is of importance, for Mr. Inglis cannot be accused of either ignorance or partiality. Yet the criterion applied by him with brilliant results is a startling one. If it is founded upon fact—and this it is impossible to doubt—then there is indeed a law of growth to

be observed in the history of the architecture of bridges, a law whose manifestation is no doubt modified by an unimaginable variety of local conditions, but which yet has been, and remains, operative in all places and at all times.

§ 3

At this point it becomes incumbent upon us to see if we cannot discover a standard wherewith the rate of growth of a bridge may be compared. We have already, by dividing the process of growth into a number of fixed units, seen how it may be measured merely by counting the number of arches composing the bridge. But this is not enough. When the question of strength was being inquired into it was found that some standard of comparison was necessary as well as a method of estimating its magnitude. This standard was provided by the mass and the movement of the load. Again, when discussing the quality of permanence we were as much concerned to find something whereby to pronounce accurate judgment upon it as we were to measure the degree of it in years. Now that the process of growth has proved to be equally commensurable, equally made up of a number of fixed units determined by nature, where shall we find the larger unit, fixed also, that is determined by man ?

It will be recalled that the structural unit of the bridge was seen to occupy a central position between two such boundaries, one larger and one smaller than this unit. On the one hand the structural unit was composed of a number of lesser units of material. On the other hand the structural unit combined with a number of other such units to form the totality of the bridge. A curious relationship was found to exist between these three entities. The greater and the smaller

were rigid and inflexible, while the midmost one, the single arch, notwithstanding this adjacent rigidity on either side, was yielding and elastic. The piece of stone was there, the bridge was there, or at least (shall we say ?) the *idea* of the bridge : these were the things wherewith the builder set to work, these were his fixed equipment, the given quantities, the *données* of his problem. Idea and material : these were what he had to work with. Idea and structural unit : these are the fixed quantities between which hovers the variable rate of growth. Let us see what this statement implies. That the structural unit has a fixed rate of growth is a fact wherewith we are already familiar. Is a constant velocity also possible for the rate of growth of the idea, for the process of ideation, of *conception ?*

Let us first look a little more carefully into the nature of this process. It is, we may say, the planning of a piece of work in all its elements, in all its bearings and aspects ; it means an ingestion of the whole of its subject, a full development of its manner, by our imaginative powers. It means a proper expression not only of this part of the subject or that, but of them all, separately and jointly. It is a process, in other words, similar to that which is so well summed up in the word *to understand*, a word which applies equally to the highly similar acts of creative conception and recreative perception. And while we are considering this word let me quote the famous saying of the Abbé Terrasson, that the length of a book is not to be reckoned by the number of its pages, but by *the time necessary for its understanding*.

Now, how can this time be in any way commensurable except with reference to a fixed normal velocity of understanding ? Without such a standard Terrasson's statement becomes utter nonsense, and along with it a considerable portion of the whole body of artistic theory and criticism must fall to the

ground. But if there were no such standard why should we continue to marvel at those strange phenomena in which it is supplanted by the erratic laws of genius? How should we think the production of a *Vathek* extraordinary if there were no such thing as an ordinary rate of production? For what we marvel at in *Vathek* and suchlike performances is not the speed of the hand that wrote it, but the speed of the brain that conceived it. It is this high intellectual activity, so far removed above the normal, that makes a Shakespeare or a Christopher Wren appear almost, if not quite, superhuman. Other and lesser men have produced nearly as many works, but not on the same vast themes, not with such a profusion of vital power; not, as these, racing down the utmost orbits of thought with a conceptual swiftness that is incomparable.

Need I say more to make the idea of a fixed rate of conception appear an authoritative condition of human life and thought? Not, I believe, to the architectural reader. To him this lengthy, painful and complex process will be more familiar, perhaps, as a measurable thing, than it is to the writer or the scientific inventor even. In especial he will know what it is to be driven to attempt, and to attempt in vain, an acceleration of the rate of conception that may keep pace with the rate of execution. But I must not anticipate. Before we come to this stage in the relationship between the two velocities of brain and hand we must examine how they are co-ordinated in the kind of bridge with which we have thus far been dealing.

This bridge we have called the synthetic bridge. It is composed of a number of separate arches, one arch being built every year, and being supported independently of its neighbours. Now it is clear that before the first arch is built the idea of the bridge must be, such as it is, complete in the builder's mind. The builder will not set up an arch in the middle of a river and design his bridge afterwards. This

design need not necessarily be complete before the building of the arch is complete : indeed, unless exhaustive experiments have been made this could scarcely be possible. No matter how much, however, the design may still lack at the moment when the first piers and arch are begun, it will readily be admitted that by the time this arch is finished the design must be, in its general outline, finished too. All the features of the bridge, its proportions, its behaviour, its prospect of life, are contained in this first arch just as fully, as surely, as the leaves of a flower are contained in the bud. We may say, then, that the conception of the whole of the bridge occupies roughly the same space of time as the building of one of its structural units. These two processes are simultaneous and coeval. And since the time needed for the building of the entire bridge is a multiple of the time needed for a single arch, we may say that it is also a multiple of the period of conception. We have already learnt to describe the synthetic bridge from its qualities of strength and permanence. The definition which we now have before us is indicative rather of the manner whereby the bridge comes into being. The period of growth a multiple of the period of conception : this is how, from the genetic angle of view, the synthetic bridge may be known. Here we have the great characteristic of its manner of making.

§ 4

As the rate of growth of the bridge increases so the arch is lengthened, and as the arch is lengthened the substance of pier and spandril gradually contracts. The volume of solid masonry to a structural unit was, we saw, constant, and what was added to the length must be taken out of the thickness. This statement is very nearly correct, but not quite,

PONTE DI CECCO, ASCOLI PICENO

and before continuing it may be well to examine precisely what does happen.

It is not, we saw, possible for one mason to place a stone on top of another with any great variation of speed. But it is easy for ten, or twenty, or fifty masons to be placing stones next to one another, to repeat, that is to say, the process of superposition standing side by side. The *width* of a bridge may therefore exhibit considerable variations quite independently of the rate of growth. The point is only of secondary importance, but there is no harm in being precise. Let it be noted, then, that what remains roughly constant throughout the changes in the rate of growth is not the volume of the solid masonry, it is the elevational area of this masonry, it is the arch and pier as they are seen from the stream—their height and girth, but not their width across the bridge. This constant area is spread out to a greater length, and the result is a decrease in the thickness of the arch and in that of the pier.

When I say that the thickness of the arch grows less I refer of course to its *relative* thickness, that is to say the volume of its spandril in relation to its span. But the narrowing of the pier is a decrease in absolute thickness : its volume grows less regardless of the increased span. The stuff that is taken away from the pier really does go to lengthen the arch at the point where it is thinnest. Unfortunately it is difficult to obtain any precise verification of this law, since there is no mediæval bridge existing that does not include piers belonging to all imaginable periods of history. Nor is it possible, except in a very few instances, to date any of the work done since the bridge was first erected. Most bridges built before the sixteenth century, however, contain one or more piers whose width is in the neighbourhood of twenty feet, and it is reasonable to assume that a pier of a less width is the exception rather

than the rule for that period. Wider piers still were by no means uncommon, as, for example, in Old London Bridge. The variety of dimensions in this bridge is of course altogether exceptional, and here again it is probable that the narrower piers are of more recent origin. But even if we include all of these the average width still remains above twenty feet. Now the bridge at Boroughbridge, in Yorkshire, the narrowest of whose three spans is fifty-four feet, has one pier measuring seven feet six inches, a fact which must cause us to place it fairly late among English bridges. If I may return once more to London, it may be observed that while the arches of the new London Bridge are of wider span than those of old Westminster Bridge—its predecessor by a good three-quarters of a century—its piers are at the same time narrower than those of the older bridge.

The conditions of growth are not the only ones that prevent an increase of masonry volume concomitant with the increase in linear measurement. Two other factors may be mentioned. The first is a familiar but still insufficiently explored biological law first enunciated by Lamarck, according to whom the various parts of a living body are connected by some faculty which balances one part against the other. Thus if one of a pair of organs be removed the other will grow larger, and if one be subject to abnormal growth the other will decrease in size. The growth of the frog presents some fascinating examples of a balanced growth and diminution in which some of the elements disappear altogether. On the other hand, experiments have been made with certain kinds of lower animals, where, two individuals of unequal size being grafted together, the larger one would diminish and the smaller increase in size until both were equal. In all these phenomena one common tendency is to be observed, a tendency towards the maintenance of an equilibrium, of a balanced aggregate

which is constant for a given organism. Thus there is a roughly constant aggregate for the structural unit of which a bridge is made up, and no sooner does one of the elements comprised in the unit threaten to increase this constant than the other member bestirs itself to restore the balance. Like most of the laws of nature, this one too has a bearing upon æsthetics which is so obvious that it has no doubt already occurred to the reader. In music, as in the visual arts, a parallel increase, decrease, ascent, descent or what not, that is not set off by a contrasting element, unopposed by some suitable counter-movement, constitutes one of the most flagrant breaches of the law of composition. If a tall column be superposed upon a shorter one, the taller will be not only narrower in proportion to its length, it will also, in a carefully designed building, be in fact narrower by a measurable quantity than the shorter column below. The principle is one which appears to govern all formal objects placed in some definite visual or aural relation to one another.

The other principle restraining the growth of volume of the structural unit derives from the fact that no increase in volume is possible without a corresponding increase in weight. Constant volume means constant weight, and it is obviously of some importance that the weight of the arch and pier should not become unduly great even though the arch be flung across a wider distance. The growth of all organisms is narrowly limited by this increase in weight without which it cannot of course take place. A plant, an animal, a human being, none of these could exceed the average dimensions of their species without their stability, and, with animals, their powers of locomotion, incurring the gravest risk. A bird of the size of an ostrich must necessarily lack the strength to fly, while no tree rising to a height of a thousand feet could maintain itself in an upright position. Not only this, but the greater its

circumference, within limits, the more difficult it would be for it to do this. Now the material whereof the bridge is built is still, at the present stage of our survey, the same, and its strength is almost quite unchanging. We have already seen for what reasons the early builder of permanent bridges established the law of the greatest permissible mass. He made his masonry as voluminous as the flow of the water would allow, but he found another, though perhaps not equally important, restraining factor in the strength of the masonry itself. He sought out his maximum : to go beyond this would be to sustain unavoidable injury not only from the pent-up stream without the bridge, but also from a failure of the forces within it.

The early bridge having thickened its structural units to the utmost degree that was consonant with a reasonable safety, its successors did not dare to increase the burden, even though the length of the unit had to be increased. The greatest burden of all fell of course upon the base of the pier, where the weight of the whole structure was concentrated. What was added to the volume at one point must be taken away from another : the same is true of the weight. A bridge of the proportions of Old London Bridge, if built across a valley at a ten times greater size, would not only disclaim all kinship with the kind of structure which we call a bridge, but it would be a dynamical impossibility also. As a thing is magnified, so the relation of its parts must change. The formal differentiation, therefore, does not spring from the changing rate of growth only. Form and velocity are no more closely bound up together than form and size. In addition to the variations in rate of growth and dimension, however, there is a change also in the behaviour of the bridge, a change equally connected with the morphological evolution, and one which we will examine in the following chapter, where the

synthetic bridge will be left behind for good. The proportions of the bridge may change gradually throughout the centuries, but so long as the synthetic mode of building prevails its behaviour will be of the same kind, though differing in degree. By what this mode is to be followed it is therefore our next business to inquire.

CHAPTER V

§ I

THE formal differentiation that springs from the increasing rate of growth presents one aspect which is more important than any other that we may discover. Just as a tree has its roots below the surface of the earth, so the bridge must drive down *its* roots below the surface of the water. It is there that we have looked for the primary seat of strength: it is there that its life and death are in the first instance debated, whatever else may follow when the full burden comes to be assumed. The effect of a structural change cannot be more considerable anywhere than it is at this radical, this fundamental point, the root and basis of the whole work. What happens there while the arches stretch themselves out and the substance of the bridge is extenuated ?

We may sum up the new conditions under three heads. First, the volume and hence the mass of the bridge remains

the same. Secondly, the points of support afforded this mass become less numerous. Thirdly, each several support is founded upon a smaller area than before. The resources of the bridge, therefore, in its battle against the natural, the external forces, are depleted. We have seen that the highest sensitiveness to these forces was to be found in the pier, and that in the early bridge this part must consequently grow to the largest allowable bulk. The effect of the increasing rate of growth is to diminish this bulk. In order that this may happen without detriment to the stability of the bridge it is necessary that the sensitiveness of the pier should be correspondingly diminished, or that its strength should increase. Elsewhere these two properties are independent and conditioned each by a separate factor, but in the pier this is not so. The first and greatest danger of which the pier is sensible is that of subsidence, and its sensitiveness to this danger will be in inverse proportion to the strength wherewith it is able to combat it. If the bearing surface of the pier decreases, as it is found to do in consequence of the increasing rate of growth, it follows that its sensitiveness must be smaller, its strength greater. The liberal volume, the heavy mass, in which its safety had hitherto resided, must be replaced by some new element of strength. What is this element ?

In order to answer this question we only have to look towards the point from which the pier is threatened. It is above all sensitive to an inadequate foundation, to the strength or weakness of the earth's surface. The only way to decrease its sensitiveness with regard to this surface is for the pier to make itself independent of it : to go below it for the support it needs. How far below ? Deeper and deeper, until the necessary firmness is encountered. Something there will be no doubt, rock, gravel or what not, upon which the pier may rest without requiring to spread itself out as before. The

eighteenth-century bridges of the French province of Languedoc were built precisely in this fashion. No matter how much trouble must be taken or how great an expense incurred, the bed of the river was excavated till a solid layer of rock appeared. Upon this rock the pier was founded, and founded, of course, with as good a prospect of permanence as is possible in the building of bridges. The difficulties attending such an operation are not only immense, they are impossible to estimate beforehand. Every one of the Languedoc bridges constructed with their piers standing on a solid bed of rock cost much more to build than was at first reckoned probable, and the method was one which did not long commend itself. Its difficulties are of two kinds. There is, first, the work of excavation itself, which is much the same for a bridge as it is for any other building, always hazardous, always experimental. But in addition to this the bridge-builder has to remove the water from the spot in which he is digging.

This task of laying bare the bed of the river, and of keeping it bare in the middle of the river's flow, is one that has to be accomplished before digging may begin. The device by which it is made possible, a device known as the cofferdam, opens the first stage in the evolution of the modern bridge. How was a bridge-pier begun before this innovation came about? The bed of the river was sounded, a spot chosen, and on this spot large boulders were flung down. In many places a row of stakes was driven in round about the boulders to keep them in their place. Gradually, somewhere near the lowest water-level, a horizontal working surface was contrived, above which the masonry rose in level and regular courses. The means wherewith to construct a cofferdam were already at hand. Drive in your circle of stakes at the very beginning, before a single stone is put down, as thickly as you can; or

else close the interstices between them by means of planking dropped into a groove in the side of the piles.

An enclosure, more or less impervious, will thus be formed within which the site of the excavation may be exposed. All that is wanted is a pump, driven by human or animal power or else by means of a water-wheel. This is the cofferdam. Once the water is kept off the place where the pier is to rise you may dig at your leisure until a stratum of the requisite firmness is reached. There you will lay the foundation of your pier, now no longer sensitive to the failures of the earth's surface. Below that surface a foothold has been secured whose firmness is intrinsically high, not, as before, proportionate to the width of the area taken up. Nor does it require to be compressed by means of the greatest possible initial weight of masonry. The path is clear for the formal changes that must follow the accelerated rate of growth. Longer arches, fewer and narrower piers, all these signs may now be expected to become manifest in an increasing measure, the chief obstacle to such a development having been removed.

§ 2

To excavate until you strike a bed of rock is satisfactory enough as a means of securing stability, but I have already pointed out by which great drawbacks the method is accompanied. The result is certain: the efforts that will be necessary to achieve this result cannot be at all adequately known. Even in our own day it is impossible to predict the amount of work involved in such an excavation. Bridges are built in a much more rapid fashion nowadays, and it would be useless to look for a contemporary example among bridges. While I am writing an army of twenty thousand labourers

are bringing one of the greatest engineering works of the age towards completion. So highly have our executive powers become developed since the early days of the cofferdam that nothing smaller than the Sennar Dam, on the Blue Nile in Egypt, can truthfully represent the effort expended upon a great bridge in the pre-industrial age. The site of this dam had been probed a hundred times, the excavations were planned to a nicety, and yet, in the early months of 1924, the unavoidable irregularity supervened. A dip was discovered in the rocky bed of the river, and in this hollow a stable foundation was sought again and again, to be found at last at a depth far greater than that foreseen by the engineers.

Now in the building of a dam the rocky foundation is needed not only to give stability, but in order that the structure may arrest the passage of water throughout its entire height. It is inextricably bound up with the function of the dam, which would be useless if it rested upon a substance less impenetrable than itself. In a bridge the rocky foundation is only a means of giving added strength. Cannot this strength be obtained in any other way?

It will be recalled that the bouldery foundation upon which the earlier bridge-pier was constructed had to be restrained by means of a row of piles. A similar row was used to form a cofferdam. The stake or pile has, it is well known, been used since time immemorial as a fastening. It still had not been used as a support. The difference is important. To moor a boat to a stake is not the same thing as to build a house upon a cluster of stakes. Nor can the building of a masonry pier on such a cluster be compared to the building of a wooden hut. To hold the stones together with piles was easy: it was, in fact, the oldest way of building piers and breakwaters about our harbours. The old Cobb at Lyme Regis is an example. But how could the stone be laid

on the top of the piles? When Smeaton decided to rebuild Eddystone lighthouse in stone he met with nothing but ridicule on every side. The experience of centuries seemed to inculcate the necessity of crowning a wooden substructure with a framed building also of wood. The principle is a sound one. In allowing a less permanent material to enter into the composition of our structure we shall be in danger of setting the permanence of the other parts at naught. Especially is this bound to happen if the material possessing the higher rate of decay is used in such a place that the integrity of the whole structure depends upon it. Add a wooden parapet or gateway to the bridge of stone on all account, but if the bridge of stone be made to repose on wooden piles its life will be not a day longer than that of the piles.

The use of the pile presented in a happy combination the advantages of both of the older methods; or one might say more briefly that by its means the ultimate benefits of excavation were enjoyed without its drawbacks and difficulties. If on the one hand it was unnecessary to spread out the masonry over the largest possible area, and to compress the earth's surface under the heaviest possible load of stone, on the other hand the digging up of the river's bed could also be dispensed with. The bed must still, however, be laid bare. The piles must be driven in to the whole of their length, until their tops come level with the earth. The unequally projecting ends must then be shorn to observe the same uniform level; the earth must be packed hard and smoothed between them; a wooden platform must be constructed upon this foundation. Not till then might the first stone be laid. Moreover, when the masonry had reached the height of a foot or two this wooden substructure, together with the lowermost masonry course, required to be covered up with earth. All this could not be done by men working

under water, so that the cofferdam was still indispensable. The second stage in the evolution of the modern bridge is represented by the combined use of pile and cofferdam. At the beginning of this stage excavation was not yet wholly abandoned: towards the end it gradually disappeared. I refer of course to just so much digging as would permit the wooden platform and first masonry course to lie below the bed of the river. It was indeed desirable that it should be thus protected by an unbroken expanse of soil, especially in that this device contributed materially to the permanence of the bridge. But the increasing rate of growth would not long tolerate such a dilatory and incalculable process as excavation to be anywhere employed.

Next after excavation it is the turn of pumping to be eliminated. Both depend on factors outside human control: both are inimical (I will not say equally) to the new acceleration of the rate of growth. The amount of water that makes its way through the wooden sides of the cofferdam is something that the bridge-builder has power to regulate. He may even set his stakes so close together, so thickly serried, that once pumped out the water is excluded altogether. But the water that insinuates itself through the soil on which he works depends on one circumstance and one only: the porosity of that soil. Its porosity may be decreased by compression, but only in a slight degree. So long as the cofferdam is built in the water, therefore, it will present in the earthen bottom a vulnerable point which only continued pumping can defend. The bridge-builder who had to work with spade and pump was as much at the mercy of the elements as farmer or sailor: he had to be more than a mason, he had to fight his way through earth and water before he could lay the first stone of his proper handiwork. It is not to be wondered at that a great bridge-builder like Perronet excelled no less as a hydraulic engineer

THE BRIDGE OF THE EMPEROR VALERIAN, SHUSTER, PERSIA

than he did as a constructor. Among the designs left us by him none are more numerous or more conspicuous than those that illustrate pumping machinery.

Now the cofferdam is, as the name shows clearly enough, a dam in the shape of a coffer. It was usual at first to build the coffer in the water, and then to empty it by means of pumps. The next advance in the technique of bridge foundation was made when the coffer (or caisson, as it now—the innovation being of French origin—came to be called) was constructed on shore and dropped into the stream in such a way that no water could penetrate into it. Into this dry box the masons might descend to their work without thought of pumping, and remain as though ensconced in the hold of a ship. But it will be recalled that before they could lay the first stone the ground had to be got in readiness by means of a dual operation. First the heads of the piles must be cut off level with the ground and one another, and secondly, upon these piles must be disposed the timber platform for the masonry. How was this operation performed? The caisson had no sooner been conceived than a number of engineers (including, of course, the indefatigable Perronet) set to work devising a subaqueous saw which, manipulated from a boat, would cut off the heads of the piles under water. Such an appliance was offered to the Commissioners for Westminster Bridge, but it would appear that the experiment was not successful. In 1757, however, the French bridge-builder de Voglie was using one for his bridge at Saumur. By its means he was able to trim his piles at a depth of fifteen feet under water. The other half of the process was by far the easier. Why construct a separate platform and lower it into position on the pile-heads before the caisson was brought down the stream? Why do this when the bottom of the caisson itself might very well be constructed as a permanent platform, the sides being detached from it and

they alone removed when the pier had risen above the water's level ?

One more development remains to be considered, after which we may leave the subject of foundations. The use of piles as a support was subject to an important condition. The piles must not project each one above the solid earthen mass in which they are embedded. You cannot balance a masonry structure on the top of a free-standing post : there must be a flat surface for this structure to rest upon, a bed reinforced with piles or not, but still a bed. The cofferdam represents the bridge-builder's way of descending to this bed. There remains another and easier course open to him : he may raise up this bed towards the surface of the water. This method is the direct predecessor of our modern concrete foundation ; it was invented by Gauthey, the famous French civil engineer, and extensively used by him throughout the province of Burgundy, where he was director of public works, or, as we should say, county engineer. His piles were cut off at only eighteen inches or two feet below water-level ; instead of driving them to their whole length into the bed of the river he filled the space between them with concrete contained in an enclosure of sloping piles. The concrete was so mixed that it would set quickly and firmly under water. When piles and concrete filling had become one solid and inextricable mass the first course of masonry was laid on the usual wooden grid, but with its bed several inches under the lowest level of the water. Gauthey's system was new, untried and at first excessively dangerous, for in a few years three of his bridges came down shortly after completion owing to some deficiency of the concrete base.

But a new era had set in. Instead of building lengthily, laboriously and expensively for the ages, the late eighteenth century already began to perfect our modern practice of

building swiftly, easily and cheaply for the need of the moment only. And not only were Gauthey's bridges quick and cheap to build, but the system of building was such that a really accurate estimate of the cost was for the first time made possible in advance of the work. Here it was no longer necessary to labour in the dark, to look to the morrow with hopefulness and faith, trusting that what was well begun by one generation would be well ended by another. Instead, the plans were drawn up, the cost reckoned out to a shilling, the work timed to be completed in just so many weeks. No wonder a bridge-builder who went about his business in this fashion inspired the confidence of everyone, though bridge after bridge collapsed. Indeed, these casualties were deemed of but small account since the saving effected in the building of three bridges would more than pay for the re-erection of one that was lost, not reckoning, of course, the toll of human lives.

§ 3

The conditions of permanence were twofold : first, a scrupulous choice of just those materials—a full employment of all those means—whereby the utmost durability might be achieved ; and, secondly, a mode of construction which would enable the edifice to recreate any one of its parts as soon as it should fail, and thus to enjoy a length of life far in excess of that of each individual part. The first of these conditions has already vanished in the evolution of the rate of growth. A structure still made of the most permanent material that could be procured is entrusted to supports made of a material of far less permanence. The strongest masonry in the world cannot stand up longer than the substructure upon which it rests. In point of strength the piled masonry bridge may possess primarily the attributes of stone : in point

of permanence its dominant qualities are those of wood. It is not the weakness of the material that is at fault: it is what was in a previous passage described as its chemical permanence. The first sign of permanence, therefore, is absent from the piled bridge. What of the second?

The second sign was, it will be recalled, the synthetic organization of its parts, each mechanically independent of the next, each admitting of localized fracture and localized repair. Now this independence was achieved by the expansion of the pier to the greatest possible bulk, and the proportionate contraction of the arch. The evolution we have been watching has brought us farther and farther away from these characteristics. A similar volume of masonry stretched over a greater length and borne on a more exiguous support: this is how the increasing rate of growth makes itself manifest. It will be observed that the synthetic mode of construction was bound to disappear. It fell into desuetude gradually and in a way that caused its demise to be almost unnoticed, but not so gradually as it would have done had not its military value been instrumental in prolonging its life. This military interest attaching to the synthetic bridge has already been described, and need not detain us here. As the arches lengthened and the piers shrank to a smaller compass a moment came when, to the bridge-builder's astonishment, the pier did not provide adequate abutment to the arch. The independent arch, it was found, had gone, and clearly gone for ever, and with it the synthetic bridge of which it formed such an indispensable element.

Still, though the independent arch had ceased to be associated with the ideal of permanence, it still remained a necessary condition of building. Once upon a time the question which the bridge-builder asked himself had been: What is the *utmost* degree of stability, of mechanical indepen-

dence, that may be imparted to my pier and arch? This question now no longer preoccupied him; instead he asked: What is the *least* degree of stability, of mechanical independence, that will permit me to construct my arches singly without causing them to fall down during the building? The ratio of void to solid increased and at last approached the utmost limits of safety. Rules were formulated, a fixed minimum of masonry which was said to contain a guarantee of security. The rule grew more and more empirical, the minimum contracted boldly. According to some authorities the span of the arch must not exceed five times the thickness of the pier; a little afterwards a sixfold latitude was said by others to be permissible. The formula could not be tested anywhere outside the domain of bridge-building, the only one in which arches of suchlike proportions were ever employed. Still the minimum grew less, and at length disaster followed. The great bridge at Mantes was constructed on the synthetic principle, arch by arch, its arches being adjudged independent by the foremost authorities of the day. They were not; one arch flung down another, exhibiting to all the inadequacy of the pier to buttress them, to resist their outward thrust, to isolate the forces active within them. The synthetic bridge was now observed to be at last extinct.

It should not be imagined, however, that even the pioneers of the new construction were blind to the great advantages presented by the synthetic bridge. The greatest of them all, Perronet, was a strong advocate of a mode of construction which we may call the *divided*, though he does not appear to have had an opportunity of erecting such a bridge himself. By dividing a bridge of many arches into three or more parts he proposed that each of these parts, which would comprise a number of arches, should be given such independence as the individual arches once possessed. To this end every

third or fourth pier, say, was to be a proper abutment pier, while the intermediary ones would be more exiguous and would make no attempt to discharge this function. Gabriel's well-known bridge at Blois is of this type, its eleven arches being very beautifully divided into three groups, of which the central one contains three and each of the others four. And since either of the two dividing piers possesses more than one-quarter of the width of the largest adjoining arch their buttressing power is, it will be seen, perfectly effective.

But the divided bridge did not come to stay, for its principle, admirable in every respect but this, did not coincide with the tendency which was the undoing of the synthetic bridge and the origin of its successor. What sort of a bridge was this successor ? Once the impulse that begot the synthetic bridge had died, once the manner of building of this bridge had become a lost art, there was no turning back, no retracing of the progress so laboriously made. The rate of growth must continue to increase, but how ? A genius is always nature's answer to some such question as this, and a genius was the answer it supplied to the present one. The mishap to the bridge at Mantes is of historical significance, for it convinced Perronet of the fallaciousness of the current rules for the construction of independent arches, and caused him altogether to abandon the building of such. And presently we find him producing that astonishing masterpiece of engineering, the first true continuous bridge, that over the Seine at Neuilly, in which the piers are no longer one-fifth of the arches in width, not even one-sixth, but one-tenth ! No wonder his colleagues to a man shook their heads at such unprecedented boldness, and forespelt defeat for him who had been guilty of it ! But Perronet triumphed, as we all know ; and yet a quarter of a century later the whole engineering profession in England was busy discussing how the arches

for the new London Bridge might be built to stand independently by the use of this or that formula. Even such a skilful and justly famous engineer as Smeaton, when his design was criticized for lacking the synthetic quality, could only weakly protest that the charge was false and affirm the independence of his arches, without, however, being able to supply other proof than that afforded by a dying tradition whose accuracy he knew not how to test.

§ 4

The new type of bridge has been called the continuous: what exactly is meant by this term? In another chapter we employed the image of a man in the act of walking. Animated by an idea of continuous motion, the body of the man was yet so made that it could not propel itself with this ideal motion. The idea was continuous, the act had to be discontinuous. In translating his idea into action it became necessary that the man should break it up into a number of successive fractions called steps. Just such a breaking-up of motion was, we observed, imposed upon the bridge. The interval separating the two banks of a stream is divided into a convenient number of stages, and each stage is traversed in an arch. In the continuous bridge this division is still present, but the arches are no longer separate, they are no longer built one by one, summer by summer. Though the distance is still covered in a succession of leaps, the movement of the bridge is not arrested at each of the points of support. This movement has been integrated: it is continuous. The natural conditions which set a limit to the contraction of the pier have been overcome: those that decree the building of one arch in a season are now overcome also. These impediments once removed, the

pursuit of integration continues with the gathered speed of a dammed stream set loose. The bridge is no longer built up of independent parts fashioned one at a time: it issues whole from the hands of its maker. The motion imparted to it by a moving vehicle is not now confined within the rigid boundaries set up by the great piers: it proceeds from one end of the bridge to the other.

Let us examine the bridge once more in its social setting. Product and instrument of a civilization, its growth is analogous with the growth of that civilization: it is governed by similar laws, it answers a purpose that is related to the other's ultimate end. The function of the bridge has been dealt with elsewhere, and we are at present concerned only with the manner of its growth. The growth varies in speed, and to these variations of speed correspond the variations of form that may be observed in all the world's bridges. The rate of growth, however, is as closely connected with the progress of a civilization as is the function of the bridge. The slow initial rate was productive of the quality of permanence, and it was found that this quality had been actively and consistently pursued by the builder, had assumed the importance of an ideal. This ideal it was that regulated the speed and manner of the bridge's growth. When the speed increases and the manner alters, it is because the ideal of permanence loses its power over the minds of the builders. As a civilization grows older its prospect of life diminishes, and the desire to give the utmost degree of permanence to its organs suffers a corresponding enfeeblement. What is the desire that takes its place, if its place is taken by anything? What is the new ideal that supplants the old?

"I am profoundly impressed," said the President of the United States in a recent speech, "by the fact that the structure of modern society is essentially a unity, destined to stand or

A CANAL BRIDGE, VENICE

fall as such." The fact is one by which most of us are profoundly impressed; no aspect of modern civilization can surely be more familiar than this "essential unity." While permanence was a conquest of time, this new ideal of integration represents a conquest of space. The purpose of each is similar in its own particular realm, for it is to impart to the objects wherewith it is concerned the greatest possible continuity. It will be seen that the bridge-builder is but obeying an impulse that is universally present; President Coolidge's remark about modern society might with equal truth be applied to the continuous bridge devised by Perronet. Nor do the other arts fail to share in the general movement. What do we find, for example, in literature? On the one hand you have the series of unrelated incident that constitutes the epic, the romance, or even the early novel of adventure—incident linked together, if at all, by the barest thread of sequence or of biographical identity, but strengthened and made memorable by its dramatic vividness, its hard and deliberate economy of statement, and, in verse, by technical devices orginated as much for their mnemonic usefulness as for the opportunities they afford of poignant expression. On the other you have the tragedy, the ode and sonnet, the new psychological novel, in which a steady current of incident or speculation moves uninterruptedly to its foreordained close. Take away a line from the *Grecian Urn*, *Wuthering Heights*, or even (with all respect to our actor-managers) *Hamlet* or *Lear*, and the structure is impoverished, the meaning alters, the work loses its large and precious unity. This same unity, then, is the difference between the one kind of art and the other. To this end is the process of integration applied. The early art is built up, collated, the work of many moods, many men, perhaps of several generations: the later is conceived as a whole and made as a whole, by a single generation or even by a single man.

In painting the contrast is equally—if not more—conspicuous. A long and arduous path of technical conquest separates the completely homogeneous and scrupulously consistent visions of Manet or Velasquez from the composite pictures of the primitives, in which the celebrated unities, infinitely sacrosanct to a fully matured art, are treated with the scantiest respect. But, as in poetry, we find the pursuit of integration accompanied by a corresponding loss in sharpness and permanence of definition, in intensity of intellectual sight. The hard, graven line is not only the most concise, the most ardent, the most quintessential means of pictorial expression : it is also the most definitive and the most durable. The bright motionless limbs, the cloudy garments, the flowers and foliage and sky of Botticelli's *Primaveri* have seen their colours change with the centuries, and they will continue to darken and lighten and finally fade like all the rainbows that ever were ; but the sweet firm lines will not cease to clasp limbs and garments in their unalterable rigour till the picture itself falls to pieces. The individual form being thus firmly locked within its outline cannot, however, mingle with its neighbours as in the later painting where the entire field of vision is but one fluid interdependent whole, and where, as in Velasquez' *Las Meninas* let us say, the eye receives the images of painter and infanta, courtiers and jesters, the far and near, the sitting and the erect, in one indivisible experience.

What has happened here is of course precisely what has happened in the continuous bridge. The synthesis of self-balanced and self-containing units has been subjected to the process of integration, the severing outlines have disappeared ; the one mingles with the other, leans upon the other, and stands or falls with it. Continuity has been established throughout. The process is familiar in painting and literature, but much less in architecture, and this must be my excuse

for dwelling upon it at some length. Its beginning and end are often indicated by such words as *archaic* and *mature*. "The careful working of detail separately," says Sir William Flinders Petrie, "without treating it as part of a whole to be blended together, is the essential mark of archaism." Now it is to be observed that the word *archaic* possesses no corresponding noun. The adjective has remained to this day beyond reproach, and the word *archæology* still denotes the study of a beginning. *Archaism*, however, has acquired a subsidiary meaning which entirely unfits it for the task to which Sir William puts it. It no longer describes the primitive, it describes the aping of the primitive by the hyper-civilized. Archaism has ceased to mean a childhood; in our time it means a second childhood, which is not at all the same thing. It has become synonymous with anachronism. Apart from this employment of an unreliable word, however, it will be seen that the sentence quoted admirably sums up the process I have described as integration. President Coolidge's "essential unity, destined to stand or fall as such," is not more aptly descriptive of the continuous bridge than Sir William's "whole blended together."

The reason why it is made into a unity, why it is "blended together," is clear. The conceptual movement of the human mind is continuous and uninterrupted. The early painting, the early literature, the early bridge, all are discontinuous, made up of independent fragments. The fragments grow larger and at length they coincide with the whole. At a single leap the painting ceases to be a composite chart, the story is no longer a collection of stories, the bridge no longer an arrangement of rigid units. The time necessary for the execution of a work had been a multiple of the period of conception. Both periods are now the same; as the mind plans so the hand realizes. The rate of growth is equal, that is to

say, to the rate of conception : that is what integration means. At the beginning of a civilization no other ideal can approach that of permanence. But as the lease runs out—as the burden of eternity weighs less heavily upon the shoulders of each successive generation—another ideal, that of integration, claims the first place. And this ideal is not concerned with the far-off results of action but with the near, not with the centuries to come but with the continents that lie at hand. Its chief demand is that action should follow thought with the promptness and regularity of a shadow, that action, indeed, should correspond, should *coincide* with thought. Why, even the human body in motion, which was used to illustrate our argument, exhibits this new tendency just as clearly as the bridge or any other human appurtenance. In our own time the nether limbs have largely been superseded, being employed only when we choose to exercise them in so-called games, and their place has been taken by machines which impart to the human body a speed that is comparable with the speed of the human mind, and that is no longer discontinuous.

§ 5

Instead of mass and security, lightness and cheapness ; instead of experimental growth, closely calculated design. These are the changes in outlook and purpose whose effect we may observe in the rise of the continuous bridge. We have seen them at work in the building of the foundations : seen, that is, how first of all they made the continuous bridge possible. The weakening of the ideal of permanence, the shifting of the critical military foci, and now finally the discovery how to build in stone on the top of wooden piles, these are the visible influences that have thus far been active.

The continuous bridge is the result; in it the law of the greatest possible mass, the product of the early undivided search after the perdurable, is repealed; the first requisite in an arch is no longer that it shall be upheld by its immediate abutments and not press on its neighbours, but rather that it shall span a great void easily and safely, and with small expenditure of labour and material. Let us trace how these changes, begun at the foundations, continue their work and become visible in the main structure of the bridge, the portion that stands above water.

We must begin with the pier which rises from the piles, resting on the heavy wooden planking that is laid across them. The foundation is now much strengthened; there is no longer any need for the pier to spread itself over the greatest possible area of the river's bed in order that its weight may be widely distributed. On the other hand, there is every incentive for it to grow light and slender. The water is no longer impeded by the thickness of its masonry to anything approaching the same extent; hence the cut-waters have much less work to divide the rushing stream, and the importance of shaping the fabric for the easy passage of water is diminished. In most wide and slow-running streams it will be enough if the piers are simply rounded on the face. No longer was the earnest gaze of amateur mathematicians directed upon the particles of water as they struck the cut-water, no longer did they bring to birth such a dogmatic monstrosity as Batty Langley's theory, according to which the angle of repercussion, like the angle of reflection in a beam of light, was deemed equal to the angle of incidence. Gone is the vain and feverish exercise of wits upon the scientific solution of problems solved empirically centuries past. Instead new problems, far more perplexing, are to be found on all sides without number. It will be sufficient here to glance

at a few typical ones, and notably some of those attacked by Perronet himself, the greatest originator known to the history of bridge design.

Thus, the pier of the mediæval bridge presents a sort of normal type which, on plan, consists of a square (or a rectangle closely approximating to a square) with the equilateral triangle of the cutwater added at the fore and back. The bridge at Neuilly, the great continuous prototype, has long and narrow piers the outline of which on plan I can best compare with that of a spectacle-case. It has the same semicircular termination at each end. But in these Perronet had only begun his career of bold experiment and ruthless attenuation. His first design for the Pont Sainte Maxence shows the pier replaced by two columns of a pear-shaped outline in plan, with the sharp ends pointing, of course, outward, cutwater fashion. In the bridge as built, however, the piers are a trifle more substantial, but the cutwater formation has gone, the place of the single pear-shaped columns being taken by coupled columns of the ordinary circular outline. Nevertheless one-third of the bulk of the pier is thus removed, and whereas the width of the pier, in linear measurement, is one-eighth of the width of the arch opening, the area of the solid masonry in the pier is to the area of the opening as one to twelve and a half. Perronet was to pursue his search after lightness further still than that, and in his bridge at Nemours, and yet more in that at Saint Dié, where the proportion is one in eighteen (a long way from the one-in-five of the synthetic rule-of-thumb !), he may be said to have reached the utmost limits of tenuity possible in masonry construction.

The Pont Sainte Maxence and those others which followed it are, in fact, the precursors of the modern temporary bridge, in which solid piers are scarcely ever found. Instead, the superstructure rests upon a row of columns, stanchions, props,

cylinders, and the like. Thus, while the methods of construction grew bolder and feats of lightness and strength could be attempted beyond the thought of the builder of synthetic bridges, the æsthetic corollaries of bridge design became ever more complex, more perturbed in their issue, and more difficult of proper solution. It must be obvious that the design of a square block of masonry does not present the same difficulties as that of a colonnade, or series of columns, and those columns of a kind whose apparent length varies with the level of the water from which they rise. For the column is singled out to become the fine flower of a completely humanized architecture, and its design is governed by abstract formal laws of the utmost delicacy. The placing of columns side by side and one above the other is acknowledged to be one of the noblest resources of architectural art, and, I need hardly add, one which presents a tangle of problems in composition that cannot be matched elsewhere. It is because of this high cultural significance of the colonnade that the cylinders supporting the Charing Cross railway bridge, for example, with their unstudied outline and unequal, haphazard spacing, succeed in calling up to most minds the very abyss of blundering ugliness. We shall not be surprised, on the whole, to discover later on that Perronet's example is not followed in the design of urban bridges of the more permanent type. Its importance is prophetic, not actual; indeed, it really transcends its hour and its occasion, and is a foreboding of more modern methods and materials rather than an apt and rational development of masonry construction. Much of Perronet's work was equally anticipatory. He analysed not only the pier but also the arch itself into its essential components, and has left a memoir describing the construction of a stone bridge in open timber fashion, thus forestalling quite unmistakably the modern use of artificial wood.

The name of the continuous bridge has its foundation in the mutual interdependence of its arches. One arch presses sideways upon the other, the pier supporting the dead weight of the masonry only, and resisting none of the horizontal thrust which is ever present in the stones of an arch, and which is the result of its tendency to straighten itself out, to lay itself down flat, one might say. This tendency is held in check by the similar tendency of the neighbouring arch—provided, of course, that the arches are equal, as they generally are in the typical continuous bridge. Thus one arch presses back another from end to end, while the outermost halves of the two land-arches press against the abutments which unite them with the shore. So far no danger threatens the stability of the structure, though the pressure exerted by the land-arches may be considerable. But let us imagine a heavy load suddenly placed upon the crown of the middle arch, and carefully watch the result. The thrust set up by the weight of the arch itself is countered by the equal thrust set up by the equal weight of the neighbouring arch ; no more. Once these weights cease to be equal the balance too is gone ; the increased thrust caused by the new imposed load is communicated to the next arch on each side. What is its effect ? We have only to picture the motion in our minds to see that it must imply, first, the pushing-up of the crown of the adjacent arches ; secondly, and in so far as this first movement is resisted, a horizontal thrust against the feet of the next arches again, similar to that communicated by the middle arch to those immediately on either side of it. This lateral movement continues to the end of the bridge, and must finally be resisted and stopped in the abutments.

Perhaps the name *continuous*, now we have watched the bridge in the act of resisting a stress imposed upon it, will have justified itself even more clearly than before. While

PONT NEUF, PARIS

the arches of the synthetic bridge each took its load separately, bowed under it with a scarce perceptible motion of its back, pressed hard against its piers and righted itself once more without imparting any of its movement to the ample bulk of those piers, your continuous bridge causes the stress upon any one arch to echo throughout the whole series, to set up a long oscillatory movement which is only stopped at each bank. The first structural consequence to be deduced from this movement touches of course this terminal point. The word *abutment* in the synthetic bridge had held but a very limited significance. What one single pier could do—that is to say resist the spreading of only one arch—it was not difficult to make the bank of the river do also. But in the continuous bridge the abutment has to withstand the more persistent forces that leap from pier to pier to overturn it, to press it back, to break down the vertical face of the bank. A fuller development of this important member is therefore a constant characteristic of the continuous bridge. It spreads itself out laterally in heavy wings of masonry, sometimes straight, sometimes convex and buttress-like, but most often concave, gripping the wall of earth behind it with all the subtleties of curvilinear deployment, with all the structural devices of arched and vaulted form. In addition it lies profoundly entrenched in the earth beyond all this visible strength, sending out its buttresses many feet onwards and under. The spreading ramp of the Pont Neuf drawn by Mr. Brangwyn is nothing to the broad and powerful terminations of such a highly developed continuous bridge as Waterloo, for example. Indeed, the Pont Neuf is a synthetic bridge, and the widening towards the end is an inflexional treatment of the roadway rather than a true abutment of the continuous sort, which is always designed as an important addition to the system of arches, and should not properly

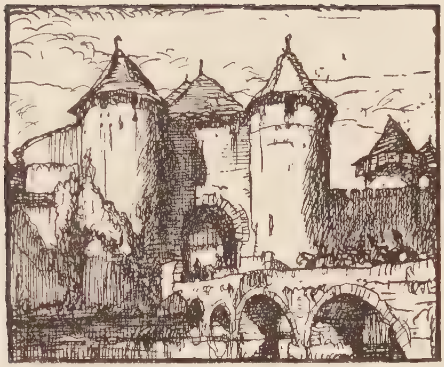
incorporate an arch or a portion of an arch in its outward sweep.

Now in addition to this communicated lateral thrust the continuous bridge also has a tendency to drive upward the crowns of its arches. We have observed the lightness and tenuity of this part to be one of the most prominent characteristics of the synthetic bridge. Indeed, the only force that may threaten to lift up the crown of an arch is a lateral inward pressure against its springing-point, a kind of pressure which is impossible in a normal way in the synthetic bridge. How should it there occur? In the continuous bridge, on the other hand, it does occur, and it is important that the crown of the arch should be kept down; hence a tendency to thicken the masonry at this point rather than to lighten it. The synthetic bridge, again, required that a weight on the crown should not be allowed to throw up the haunches of the arch on each side; to resist this kind of stress the spandrils were amply and firmly built. Lastly, the permanence of the older type of bridge lay to no small degree in its spring, its elasticity: in the power of the arch to yield without breaking any of the stones, without lastingly disturbing the fabric. But obviously in the continuous bridge such a yielding, communicated from arch to arch, shifting, returning, reverberating with the motion of the load across the top, and requiring not only the gentle bending of the isolated arch within its load of enclosing masonry, but a sideways pressure of the feet of every arch upon its pier, is not a sign of active strength and an earnest of durability, but a dangerously subversive power, a symptom of weakness. Unless it is checked it will as surely destroy the continuous bridge as it preserved the synthetic. The masonry, therefore, is closely cut and firmly and intricately bonded together; the arch is securely locked in between its piers by long tapering stones that mingle with

those laid vertically in the spandrils, and dowels are used to bind stone to stone, and piers and cramps and joggles and all the other ligaments of oak and iron that are used in building. But with the introduction of these corruptible substances into incorruptible stone we are approaching the era of temporary bridges, and but one step removed from the invention of artificial wood.

CHAPTER VI

§ I



ON the morning of September 25, 1888, a piece of stone fell from the upper part of Wren's Monument on the top of the pedestal, whence it rebounded, flew across Fish Street Hill and crashed heavily through the window of a shop. Upon examining the column it was found that the piece had been broken off by the rusting and consequent swelling of iron cramps. Such cramps have been found in other works by the same illustrious architect, who wrote that "architecture aims at eternity," and said of these adjuncts that "the architect should so poise his work as if they were not necessary." Several of his beautiful City churches have suffered injury from their presence, and even St. Paul's is not without them. We have seen in the previous chapter what they were doing there. "An arch," wrote John Smeaton, whose building of harbours and lighthouses had given him, though an engineer, a better acquaintance with the quality of eternity than Wren was ever able to make, "an arch that has a tendency to persevere in its original figure

is stronger than a much thicker arch which from its figure tends to dissolution." Those cramps and dowels were used to hold together a piece of masonry that from its figure tended to dissolution. And yet they themselves are also subject to dissolution, and may even hasten the downfall of the masonry to which they are applied. The weakness for which such an unsatisfactory remedy as this alone exists is the origin of the temporary bridge.

The introduction of a perishable material into a structure mainly composed of material of a more permanent kind began, of course, with the pile. From thence it spreads until the whole of the masonry is riddled with fragments of it. Now it is to be observed that these members discharge a highly important function in the fabric. The arch is one which from its figure tends to dissolution, and these fragments of iron and wood are there to arrest this tendency. The choice of a less permanent material, no matter for what purpose, represents, therefore, only the first stage in the decay of permanent building. The most important sign of this manner of building lies not in the material itself, but in the way in which the material is disposed. True, we may see from the use of wood or iron that the ideal of permanence is no longer as highly regarded as it was wont to be, but the permanence or otherwise of the material is yet a minor characteristic only beside the permanence of the construction. A perishable material may be used in a structure whose power of recreation will make it independent of this weakness of the material, but the most durable material in the world is useless if arranged without regard to the laws of permanent construction. Your bridge of granite will inevitably fall down if its arches tend to dissolution, and the strength of its structural units will not be able to avert its downfall for one moment.

This, then, is the chief characteristic of temporary building:

the structure tends to dissolution, and this dissolution is arrested by external means. We saw that in the permanent bridge a load imposed upon the bridge increased the mutual cohesion of its material units. The stuff of which the bridge was made became more highly compressed, was wedged together and made stronger, as the bridge bent under its burden. We may express this truth in other words by saying that in the permanent bridge the force of gravity is on the builder's side ; the weight of the bridge and of its burden are working with him to strengthen the fabric. In the temporary bridge they are working against him. He is opposing the force of gravity single-handed, and his sole instrument in this controversy is made of a material of less durability than that of the bridge itself. In the synthetic bridge the destructive force that threatened to cast down the arch was turned from an enemy into an ally ; in the temporary bridge the force of gravity has one effect and one only : to draw the material units away from each other. The force is the same, the direction in which it acts is the same, and yet the result is the opposite of what it was before.

The boundary between temporary and permanent construction is often supposed to be uncertain and wavering, no matter how profound the difference that separates the most characteristic products of either kind. This difference is held to be one of degree only, the permanence of a structure being expressed in the length of its prospective life. There is, of course, an absolute zero in this scale of duration just as in other similar scales, but in addition there is, towards its middle region, another and more important zero determined by a law of human origin. This zero is the point at which the force of gravity transfers its allegiance from the one side to the other. We have elsewhere described the quality of permanence and its absence in terms of human endeavour. Here

we may see how it may be gauged from the behaviour of the structure itself. In the temporary bridge the action of gravity is reversed just as the gearing of a motor-car reverses not the movement of the engine but its effect upon the vehicle.

This reverse action was by no means an innovation; it meant an impoverishment merely, whatever the triumphs of integration might signify from another angle of view. It was as familiar to the early bridge-builders as the system upon which their own synthetic structures were produced. For it is an important fact that a permanent arch cannot be built without the help of a temporary arch. Before an arch of stone can be commenced there must be a wooden arch or centering to support the stones as they are placed side by side. Not till the keystone was slipped into place could the destructive force of gravity be subdued and made to increase the strength of the bridge rather than abate or conquer it. Till that moment the permanent arch must rely on a temporary one for its support. If the keystone is the element which locks all the other material units in their place, it may also be described as a charm which *un*locks the fetters in which the more benevolent among the genii of gravity are held captive. But it could not do this had not the ardour of the destructive ones been momentarily curbed by means of an adscititious support of temporary construction. What happened when the permanent tradition in building was supplanted by the temporary is the usurpation by the centering of the place once rightfully held by the arch. The centering itself became the bridge. From being an incident in the process of building, an aid to the attainment of an ulterior purpose, it took the place of that purpose and became an end—nay, *the* end—in itself.

This is no idle generalization of my own; it is a striking and acute observation made by Thomas Telford, the pioneer

of temporary bridge-construction, a century ago. "The iron arch," to use his own language, "is, in fact, no more than a framing similar to that for the centering of a stone arch, with this difference, that the iron framing has little more to carry than its own weight." Little more to carry than its own weight! In other words, the centering which had before been required to carry the heavy stone structure need now, after its emancipation, possess less strength even than when its function was a purely subservient one. Is it to be wondered at that the tyranny of the permanent stone arch was at last impatiently thrown off? But it may be asked whether the temporary arch did not require like the other a centering of its own before it could be built. I will let Telford answer. "In making and putting up timber centres," he says, "there must be props and supports, and the scaffolding required for supporting the iron framing may be compared to these props and supports." That is all.

It will be observed that in the framed bridge of which we are speaking the wood of the centering has been replaced by iron. The reasons for this change are, however, external; for the constructional qualities of iron, wood and artificial wood differ in degree only. All these materials have this in common that their resistance to forces tending to pull them apart is much greater in proportion to their resistance to crushing strains than that of stone or brick. They are all of them, therefore, eminently suitable for the construction of temporary bridges, and if iron possesses this tensile strength in the highest degree it is also the more expensive. But iron and steel have another property that must of necessity weigh very heavily with the builders of the accelerated temporary bridge. With iron, according to a contemporary writer, "the time necessary for building was contracted from years to months." It was not only the strongest but also the most rapid of all

materials to work in. And hence it is when the time came to essay the most completely temporary of all bridges—the suspension bridge—that iron and steel properly came into their own. Indeed, the very name of this type of bridge tells us that it is no longer a piece here and there that acts as tie to the rest of the fabric and is subject to tensile stresses, but the whole bridge is subject to this kind of stress and no other, being itself nothing but an enormous loose-hung ligature from end to end.

If, therefore, we except the pontoon-bridge or bridge of boats, which has no place in our survey, we may well look upon the suspension bridge as the extreme type of temporary bridge-building. The first English iron bridge, that at Coalbrookdale, in Shropshire, failed some time ago after remaining up just over a hundred and twenty years. The first suspension bridge in this country lasted precisely half as long, upon which it fell down and killed several people. This period of life could of course be greatly extended to-day, and is so extended, while the numerous accidents that marked the pioneering days of the suspension bridge do not now occur. Our steel is being more and more skilfully manufactured, our structural engineers have achieved a high degree of accuracy. But make the bridge as skilfully, as securely, as durably as you may, the temporary mode of construction springs from a change of purpose, a revolution in outlook and in technique which, together with the different behaviour of its products, is sufficient to establish it as a definite and immutable type.

§ 2

It has been observed that there existed a fixed maximum for the volume of masonry in an arch, a quantity which could

not be exceeded without defeating the stability of the arch. Moreover, this maximum was seen to be reached at an early stage in the history of bridge-building, for it was necessary that the foundations of the synthetic bridge should be heavily loaded from the beginning, and that the pier should be, by virtue of its great mass, secure against any movement that might be communicated to it by the oscillating arch. The arch must therefore add to its length by subtracting from its bulk: it must draw itself out, and make the same amount of stone go a longer way. Clearly a moment must come when the thickness of stone in the spandril is insufficient to hold the long span together, when the elongation of the arch, that is, has impoverished the substance of it to a point where it must fail from sheer extenuation. It is at this moment that the aid of the ligament is invoked to hold the narrowing mass together. But the lengthening goes on, and at last it becomes necessary to take away more from the spandril than is put back at the crown. At this moment the masonry of the arch is split up into a complex of smaller members, and we get the hollow construction which is so characteristic of the temporary bridge.

The development of framed construction was of course foreseen by Perronet, who designed several stone bridges in this manner. But the framed mode of construction, which had been in use many centuries before Perronet, is especially adapted to such materials as wood and artificial wood, together with the various metals, of which iron and steel are the commonest. The reason for this is that, as we have seen, the materials of permanent construction, being pressed together by the load, are required to possess chiefly that kind of strength which resists disintegration by pressure, while the materials used in a framework stand in need of the strength which resists the separation of the particles by tension. We shall

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presently cast a glance at the more important of these new materials; for the present we still have to examine the characteristics of framed construction yet a little further. It is, we know, a kind of construction in which the load tends to weaken the structure, not, as in the permanent kind, to strengthen it. And since the yielding is a sign of weakness rather than of strength, and a cause of injury rather than a preventive agent, it follows that the temporary bridge must not yield: it must be rigid.

All of the characteristics of permanence have now, it will be seen, disappeared. The choice of the most permanent material available, and the exclusive use of that material in the vital parts of the structure, was the first of these. The disposition of this material in such a way that fractures might be localized and repaired without endangering the rest of the structure was another of great importance. This disposition ceased the moment the continuous bridge was introduced. The power to yield under the load and to spring back also characterized the permanent bridge. The temporary bridge must not yield, its parts must not glide away from one another to the smallest extent, for if they do there is no force on earth that can restore them to their position. There certainly is no such force within the bridge itself. Lastly, the permanent bridge possessed a large bulk of masonry in proportion to the area of this masonry. The exposed area was kept as small as possible because it is there that the rate of decay of the material is at its highest. But in a framed structure it is obvious that the proportion of area to volume is far greater.

Perhaps the magnitude of this increase of the surface area requires a simple illustration to be properly grasped. Let us imagine a block of stone of cubical shape, measuring ten feet each way. The volume of this block will be one thousand cubic feet, while the area of its surface exposed on all sides

to air and moisture will be six hundred square feet, or six square feet to every ten cubic feet of volume. Let this block be cut up into a number of beams, each beam being ten feet long, six inches broad and six inches wide. There will be four hundred of these beams contained in the block : the total volume of these four hundred will be the volume of the block, that is to say one thousand cubic feet. What will their area be ? The area of each beam is twenty and one-half square feet ; consequently the area of the four hundred beams will be eight thousand two hundred square feet, or more than thirteen times the area of the undivided block. The proportion of area to volume will not now be six square feet to ten cubic feet, but eighty-two square feet to the same volume.

Not only, therefore, does temporary construction elect a perishable material when others more enduring are to be had, but it arranges this material in such a manner that its destruction by chemical agencies is considerably hastened. It should not be surprising to any one to learn that the problem of preserving this area from corruption is one which to-day bids fair to eclipse the problems of construction proper. Particularly is this true of those bridges that are used for railway traffic, in which the influence of common elements such as temperature changes and the substances contained in air and water are helped in their task of dissolution by other special agencies. The vapours emitted by locomotives, the brine which trickles along the path of all trains carrying refrigerative apparatus, these constitute dangers against which engineers are still seeking an effective and, as they sometimes hope, a lasting remedy.

The highest rate of decay in a material is to be found upon the surface, and to increase this surface indefinitely is part of the temporary method of building. But the forces of destruction are not only encountered along the exposed surfaces of

the structure, they are admitted into its very heart. The incident related at the opening of the present chapter describes the other danger to which I refer. The use of metal ties in a structure—the tying of its units together " instead," as Sir Christopher Wren himself confessed to us, " of making them of that substance and form that they shall naturally poise themselves upon their own abutments—is against the rules of good architecture." But it is more than this. The French writer Viollet-le-Duc, speaking of Perronet's achievement, aptly criticizes it from the angle with which we are now concerned. " If by this means he assured himself," says Viollet, " of the solidarity of all the parts of the bridge, he at the same time placed within the masonry a destructive agency of the utmost virulence, and one which cannot fail one day to be the cause of fatal injuries." The metal tie not only, it will be remarked, suffers damage itself, it at the same time inflicts damage upon the neighbouring parts of the structure.

The attenuation which gave us the continuous bridge has here proceeded a stage further and broken up the substance of the bridge. The breaking-up has two consequences. On the one hand a larger surface of material is exposed to the air, that air which, as Sir Christopher Wren has declared once for all, is " the menstruum that consumes all materials whatever." On the other hand all hollow structures require a greater power of cohesion in the materials of which they are made, and that especially at those points where two or more members meet together. At these points ties must be introduced, and upon the permanence of these ties the permanence of the structure entirely and irrevocably depends. Unfortunately, the materials suitable for making into links and ties are mostly of a low degree of permanence. Thus it is that, while the permanent bridge—though by reason of its mode of construction independent of the permanence of its materials—

employs the most permanent material that is available, the temporary bridge, which cannot live a moment longer than one of the links that hold it together, is driven to select for those links a rapidly decaying material. Add these two characteristics to the one deduced in the previous section, and the properties of this kind of construction will be sufficiently defined. The structure it produces is of a form that tends to dissolution. This dissolution is arrested by means of members of highly concentrated cohesive strength, but of a very low degree of permanence. Finally, the material is arranged in such a way as to give the fullest scope to the agencies of chemical disintegration. Everything—structure and material alike—is of a low stability, possesses but the smallest power of endurance, while the power of recreation, by which the effects of fatigue and physical injury are cast off, is absent altogether.

§ 3

The attenuation, the breaking-up, all these things derive of course from further changes in the process of growth. We know what sort of changes, for the process has already been watched, accelerating from century to century, nay from bridge to bridge. In the temporary bridge the rate is still increasing. What is now its relation to the standard by which we have been able to measure it ? How does it compare with the rate of conception ? In the synthetic bridge it was lower than this rate, the time necessary for the execution of the work being a multiple of that required for conception. In the continuous bridge the two coincided. Clearly, if the rate of growth has still advanced it must have outstripped the rate of conception. The temporary bridge, therefore, is built more quickly than it is thought out. Or to speak once more

in time values, it takes longer to conceive than it does to execute.

Here again a sharp boundary is visible between the permanent and the temporary. So long as the time necessary for conception is not more than that required for execution the conditions of permanence are still in a measure complied with. The continuous bridge built of solid masonry which "by its figure" tends to cohere, has, it is true, lost its recreative power, and is dependent for its stability on the wooden piles and framing that support its pier. But in every other respect its construction is still of the permanent kind, as are its materials. The rate of growth has, however, to advance but one degree beyond this point of equilibrium for the signs of temporary construction to manifest themselves at once.

These signs have already been examined. Let us here devote our attention yet a little longer, therefore, to the relation between the two processes of conception and execution, a relation which assumes a new and vastly increased significance in the temporary bridge. For it will be observed that if two related processes are of a widely different duration a number of possibilities present themselves. If, for example, they commence at the same moment the shorter one will be completed before the longer. We may say, then, that if in a temporary bridge execution is begun simultaneously with conception it will have ended before conception is completed. The bridge will be built before it is fully thought out. Upon reflection it will be seen that this is a phenomenon whose presence is to be discerned in most human activities to-day, and whose effects have largely made our modern civilization what it is—a combination of immense power with highly restricted intelligence. Now what will be the result of this phenomenon when it makes its entrance into bridge architecture?

Let us consider its opposite. What happens where the execution is still unfinished at the time when the conception is completely performed? This is precisely what occurs in the synthetic bridge where, as has been found, the building goes on according to the finished plan. A different case will be found in a work wherein the process has been arrested and its continuance for some reason made impossible. The result will, of course, be a fragment. Now fragmentary works of art are everywhere to be seen, and to whatever cause their incompleteness may be due its effect upon us is much the same. We think of such a work as something broken, whether it be the thing itself that is physically shattered or merely its growth that has been prematurely broken off. In neither case is there any obstacle to our appreciation of the fragment presented to us. We may derive satisfaction from an incomplete bridge, or even a ruined one, just as we may from *Hyperion* or the torso of a Greek statue whose head and limbs have disappeared. If our appreciation of a similar torso by a modern sculptor does not enjoy quite the same degree of freedom it is because we are conscious of something besides the interruption of the work. We do not in the least mind a work of art being unfinished, but we may very easily find our sympathies alienated by a work that we know to have been left thus unfinished out of mere laziness or incompetence. We see, that is to say, no blemish in an unfinished *work*, but the suspicion that the *thought* too may be unfinished is enough to make us turn away with a feeling of disapprobation.

The disapprobation in this instance, however, is qualified. We are angry, certainly, with the artist who gives us a well-conceived torso that he could not spare the time to think out the head and limbs as well, and give us a complete whole. But we are also grateful to him for having stayed his hand at the precise point when his conceptional processes lapsed. We

should have felt much more than a mild disapprobation if to a finely planned torso he had added ill-planned limbs that contributed nothing of their own to the idea by which the torso was animated. We should not have thought: "What a pity the rest is not there!" but rather: "What is the use of those meaningless limbs?" Instead of enhancing the beauty and significance of the torso they would distract from it. They would be *ugly*, and their presence would render the whole work ugly no matter how beautiful its other several parts.

The reason for this decision is clear; it is simply that in such a work execution has gone further than conception. In the statue of which we have been speaking it has gone further because conception came to a too early end. In the temporary bridge the danger is, it will be recalled, of another kind. What is likely to happen there is not the cessation of the labour of conception, but the completion of the labour of execution before the other is finished. The result is the same. Just as there is in literature a practice colloquially known as "padding," the presence of which in any written work must at once and completely silence the responsible critic with reference to that work, so we have in bridge architecture a similar intellectual hiatus, a similar mutiny of the self-sufficient instrument against its appointed director. A thing cannot be beautiful that is not completely thought out, nor can it be criticized, and in the chapters at the end of this book, in which the æsthetics of bridge-building will be briefly examined, such bridges will be altogether dismissed from the argument.

Does this mean that we shall be unable to find beauty of any sort in a temporary bridge? By no means. The processes may not be of the same duration and yet be coterminous. No matter how rapid the execution, it is still possible for it to delay its beginning until the process of conception is

sufficiently advanced. What we must demand of a temporary bridge in which the time of conception is greater than the time of execution is that the completion of the second process shall not antedate that of the first. We shall not deem ourselves called upon to scrutinize from the æsthetic angle the bridge which is completely executed before it is completely conceived. The construction of the temporary bridge must, in other words, be preceded by a preliminary period devoted to design alone, and this period must at least be equal to the difference between the time of conception and the time of execution. The hand must be stayed till the brain is ready to instruct it.

Is such self-restraint possible to the civilized human? Possible no doubt, but not at all easy. It may be interesting, therefore, to note how the necessity for it has been in some measure circumvented. The bridge architecture of Japan has been cited as an example of the most exquisitely perfected temporary construction to which our race has attained. I have indicated that the secret of this perfection is to be sought in the relentless control that is exercised over the increasing executive facility. And what is the nature of this control? Is it of the same kind as the living control of the conceiving intelligence which it is designed to supplement? It is indeed derived from this, and it is to be found in a tradition of design, not to be confused with a structural tradition, to which it is parallel and whose place in civilization it indeed gradually assumes wherever the other weakens and, as in our own time, gives way to prolific and haphazard experiment. But in Japan the structural tradition was still in its full vigour when a code of design was established by the celebrated ninth-century architect, Hidano Takuni. This code, based upon a unit of measurement like our own similar codes of the Renaissance, appears to have fixed a clearly defined tradition that has not

been deviated from for centuries afterwards. The strictness with which it has been obeyed is all the more surprising when we remember that its elements were never committed to paper as those of our European grammarians, Palladio, Vignola and their successors in every country.

The mention of these names will remind the reader that we ourselves have not disdained the same remedy in our struggle to maintain the dominion of mind over matter. With the increasing rapidity of our means of execution we too have devised a law for the faculty of conception to obey, and the measure of this rapidity is most often (we must of course allow the exception of transcendent genius, a thing that undoubtedly exists) the measure of our adherence to this law. We have not, however, so intimately familiarized ourselves with the nature of temporary architecture as to follow the Japanese practice of facsimile reproduction. Here, as nowhere else, we shall find the supreme importance of conception recognized, for the fruits of an earlier conception are gathered again and again in safety rather than that the terrible risk of faulty and incomplete conception should be incurred, and the product offend against the laws of beauty and dethrone the human intelligence before the eyes of all. "We shall have to recognize," says Mr. Roger Fry, one of the few writers on art who have given thought to this view of the subject, "that it [*i.e.* the increasing rate of execution] may become disastrous if it outruns too far that sensibility which, without it, may perish and leave no record behind." I am not now speaking of the records that this sensibility does not leave behind, but of those that the executive ability does leave. They cannot be intelligently discussed, but that does not mean that they cannot, or indeed need not, be condemned. This question, however, is one which will find a place in another chapter.

§ 4

The temporary bridge is built of other materials than the permanent, and though the importance of a new material is most often grossly overrated it will be well if we glance at some of those that have come into fashion during the last century or so. In doing this we shall not, I trust, be in danger of subscribing to the popular fallacy according to which the material of which a structure is made determines the forms of that structure. The material is one thing, the organization of that material into structural and æsthetic forms is another, both of which are governed by the human intelligence through which all works of architecture come into being. The first of these new materials is iron, and the earliest typical form of temporary bridge the iron bridge, or, as I may perhaps be forgiven for calling it, the boilermaker's bridge. I do not, of course, wish to imply any intellectual inferiority in the useful member of society with whose name I thus make free; indeed, it cannot be doubted that in many of our modern metal bridges the ironworker and riveter have shown greater signs of intelligence than the engineer who designed them. What I believe the name does convey, however, is the complete passing of the nineteenth-century bridge from the hands of the civil into those of the mechanical engineer. This was also the view of the estimable author of the name I am defending, for it must not be thought that it is of my own invention. In the autumn of 1847 A. E. Cowper read a paper before the Institution of Mechanical Engineers, founded at Birmingham earlier in the same year, on a type of suspension bridge of which he was the inventor, and which differs from the original in that the metallic curve is constructed of rigid plates instead of a flexible chain or cable. His paper opened with a note of

apology. A subject such as he was introducing might seem to some of his friends, he thought, to belong more strictly to their civil brethren, but he hoped that his paper itself would (I quote his own words) "anticipate any objection which might have been made on that score by showing, in point of fact, that I have only been explaining a piece of boilermaker's work, which may certainly be considered to be far enough removed from civil engineering."

Alas, that Cowper's work and its successors have continued far removed from civil engineering is only too true. The estrangement has lasted too long, and though there are signs to-day of its mitigation it has had time to cover the civilized world with bridges whose social and æsthetic influence is of the most maleficent. It will be impossible here to analyse their estrangement at greater length, but I may perhaps refer to what is, I think, its most significant consequence. According to Mr. Fiander Etchells, who has written an illuminating history of the engineering profession, the distinguishing mark of the mechanical engineer is that he designs machines, while *e.g.* a structural engineer designs structures. What really happened, then, when the bridge became "a piece of boilermaker's work," was that it began to partake of the characteristics of machinery. Cowper's statement was more than an empty apology. The bridge he was about to describe to his hearers belonged, indeed, to their own sphere; it was not so much a bridge as a machine. A machine, according to the dictionary, is an apparatus for applying mechanical power, and each member of an iron bridge does indeed transmit mechanical power. And the tendency of that power is, as has already been observed, to draw the several parts of the bridge away from one another.

The great resistance which iron presents to these tensile or drawing stresses makes it eminently adapted for use in

suspension bridges, whether in the form of chains (as in many Chinese examples and in the early American bridges built by James Finley), or of cables (as in the Albert and Old Lambeth Bridges), or of round or square rods (as in Chelsea Bridge), or of flat bars grouped together (as at Hammersmith). But there is another and a much more distressing kind of bridge which metallic construction has made possible, and that is the kind that engineers have deservedly given the awkward name of *through bridge*. The connotation of this typical piece of modern scientific nomenclature is that the roadway, instead of running *over* the bridge (which then becomes a *deck bridge*) runs *through* the middle of it. But it may be asked whether it is not the river below that must be said to run through, or under, the arches of a bridge. This is indeed so, but in the *through bridge* the roadway above also runs through these arches or trusses instead of above them, though it does this longitudinally, and not, like the river, at right angles to the bridge.

The reason why the roadway should be suspended from the top of a bridge may seem somewhat obscure at first to the uninitiated, but the effect of such a bridge on the average human intelligence cannot here be examined. For the moment we will content ourselves with registering the various forms that may be taken by the metallic arch. We will imagine two kinds of abutments, the first along a vertical plane, the second on a horizontal line only, without any height or depth. To give us a model of the first kind we may put two cardboard boxes side by side with some distance between them, when the sides facing one another will represent the abutment planes between which the metallic arch is to spring. Three possibilities may now present themselves.

First, your roadway may be level with the tops of the boxes. The arch will then be made to spring from the foot of the

abutment plane, and will almost touch the roadway at the crown, just like any masonry arch. We have, in other words, a *deck bridge* with a normal upright arch.

In the second place, your roadway may be level with the bottom of the boxes. Your arch in this instance will be suspended from the tops of the boxes : you will have a common suspension bridge.

Thirdly, your roadway may be halfway between the two points. You will then have a combination of the upper and lower arches, which may either be tangential to one another or intersect one another, thus forming a sort of double loop. The first of these shapes is one which predominates in the design of cantilever bridges, of which the Forth Bridge is a notable example. It is worth remarking that in the cantilever bridge the two halves of an arch are separate and rigid units exerting no pressure one upon the other, but their general outline is derived from such a disposition of forms as I have outlined. It may be difficult to imagine anything more incredibly, monstrously ugly than some of the cantilever bridges that have been put up during the last thirty years, but the type of bridge in which the inverted arches impinge upon one another sometimes succeed in achieving this remarkable feat. The Kaisersteg at Niederschöneweide, designed by Müller-Breslau, is such a bridge.

It still remains to note the various arch-forms that are encountered in a metallic bridge of which the abutment is a horizontal line. We will take a pair of table-knives as our models, and imagine that we have to set up a miniature bridge between their upturned edges. The roadway, it is to be observed, can only come at the level of these edges. The arch may take three forms as before ; it may spring up above the road level, and give us a *through bridge ;* if we turn this upside down we shall have a reversed bowstring bridge, and finally

we may again combine the two together and have a dual metallic arch, though this time the two curves, since they must spring from the same level, do not intersect one another. A well-known bridge of this kind is to be seen at Hamburg across the Elbe, though here the roadway is indeed a little way below the springing level of the arches. In the Science Museum at South Kensington some original sketches by Alexander Nasmyth, the painter and friend of Robert Burns, and the inventor of the bow and string (since called bowstring) bridge, are preserved. They are of the eighteenth century. The first reference to the dual arch type that I have been able to find, however, is in a memoir by John Prideaux dated 1837. For nearly a century, therefore, these inverted or superposed arch-forms have been used in bridge-design, whether on the true bowstring principle or not, and yet the problem of their adequate treatment still remains to be solved. The same may be said of the multitude of framed girders, trusses and trestles that have almost made the modern railway bridge synonymous with primeval barrenness and brutality of form. A child provided with only a Meccano set and a screw-driver would have great difficulty in equalling the astonishing crudity of some of these productions, a crudity in which America has excelled all the other nations of the earth.

§ 5

The use of concrete as artificial stone is less than a century old, but it has been employed as a filling for foundations and for the interior of masonry since time immemorial. Many of the finest Roman bridges and aqueducts have a concrete core behind a casing of stone masonry, and Wren used concrete extensively. It was only towards the third decade of the

BRIDGE AT TORCELLO, VENICE

nineteenth century, however, that builders began to examine the possibilities of bare concrete construction. One of the first structures to be thus put up was a belvedere tower and entrance gates to an estate at Brighton, both designed by Barry, and it is from the builder of these, I think, that we have the discriminating title of concrete *applied as artificial stone.* It is a useful one, not only because it helps to distinguish this kind of building from that in which concrete plays a quite subordinate part, but also because it describes the much more important difference between the so-called *solid* and *reinforced* varieties, the latter of which I have indicated by the name of artificial wood. It has yet another merit of which we should be no less appreciative, for it helps us to escape from the trite and wearisome theorizing of those who are so infatuated with the comparative newness and strangeness of the material that they cannot cease from exaggerating them a hundredfold. The invention of cast-iron was heralded by no such screams of intellectual hysteria, and it may be that this is the reason for the many fine examples of craftsmanship which the material has embodied for us. The difference between cast-stone and cut stone is no greater than that between cast and wrought iron, or butter, or chocolate, or what you will, though there are clearly things that can be done with a tool that cannot also be reproduced in a mould, except in those waxen or gelatine moulds that are destroyed to liberate the cast. Apart from the fact, then, that you do not chip or scratch the surface of the moulded piece, but give it the necessary formal definition by other means, the properties of the materials are precisely the same.

It is not, however, with the difference between materials that we are here concerned so much as with the difference between modes of construction, and the name of artificial stone will tell us that, though the material itself may be

(and probably is) more perishable than quarried stone of the same density, the mode of construction to which it is applied is permanent rather than temporary, massed rather than attenuated. With artificial wood it is otherwise. The material was invented by a gardener in 1867, but the principle of continuous metallic reinforcement was applied some years earlier by Brunel, the bridge-builder. The use of lithic material for a mode of construction derived from wood was of course anticipated by Perronet three-quarters of a century earlier. Indeed, not only do we find among his memoirs calculations for the building of stone bridges of five hundred foot span, which is a good way beyond the two hundred and twenty feet of the celebrated Cabin John Bridge which carries the Washington water supply, or the two hundred and ninety-five feet of the stone bridge at Plauen, Saxony, erected in 1903: we have seen that he also left designs for stone bridges built on a principle of ligneous construction.

But to point to these designs as the precursors of the modern bridge of artificial wood without first justifying this appellation may perhaps seem a little unfair. I would claim, then, that whereas the name of artificial stone attaches a new variety of material to its well-known prototype, from which it differs only in the method of handling, that of artificial wood connects two materials which, however dissimilar in substance and origin, have yet enough structural properties in common to present more than a passing resemblance of appropriate form. It is only necessary to glance at our bridges, roofs and other modern structures made of artificial wood to see how close the resemblance is. Perhaps it may be detected even more clearly in the many watertowers that are to-day being put up either wholly of this material or at any rate supported on a framed substructure made of it. There is one at Hatfield,

in Hertfordshire, for example, which one could not at a small distance distinguish from a wooden structure.

Moreover, the forms of artificial wood are in a literal sense governed by the forms of wood itself: they are derived from actual contact with them. This is why it is so seldom used for arched or vaulted surfaces, for the wooden shuttering in which it is cast would require as much delicate and costly joinery as the making of a wooden structure of the same curvilinear form. If we view the characteristic building material of our times in this light it may be easier to justify the apparent inconsistency which everyone notes, for example, in a reinforced concrete bridge designed in open framework fashion and surmounted with a parapet containing the traditional heavy baluster of turned stone. To impose a stone balustrade on a bridge of artificial wood is no more reasonable than it would be if the bridge were built out of the wood that comes to us from the forests of Russia or Norway.

Nor when a bridge of artificial wood follows the bowstring or suspension principles which we have seen to be characteristic of metallic structures shall we feel that the new material has been rightly used. For wood is a material in which a tensional stress can be quite effectually resisted when it occurs at some points, as in the traditional design of wooden roof principals, but no one except a fool will use a wooden post merely to suspend something. There are substances much more happily conformable to such a purpose, and iron and steel belong to these, but neither wood nor artificial wood should be included among them. For embedded in this latter material are iron rods which are calculated to resist all such tensional stresses by themselves. If, then, a beam of artificial wood is used to suspend a roadway from an overhead arch the concrete in it becomes a sheathing around the metallic core, stiffening or protecting, it matters little. What

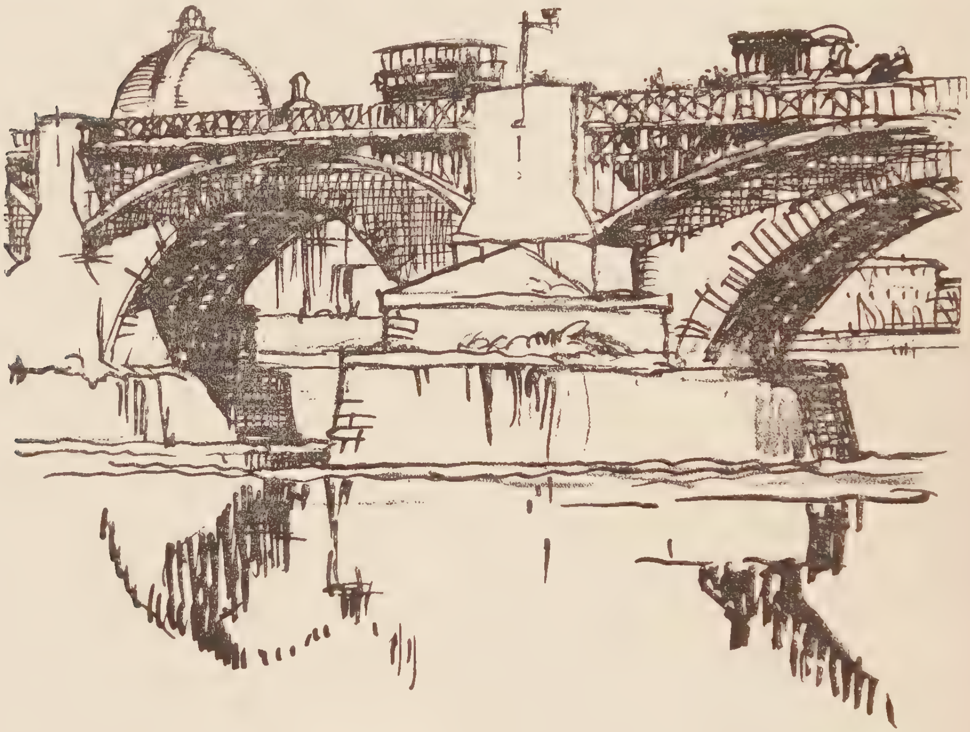
is important is that used thus reinforced concrete ceases to be the new, unfamiliar and still experimental material that it undoubtedly is. Several of Telford's early cast-iron bridges in Shropshire have been covered in concrete, but the result presents no fruitful subject for speculation. Just as concrete only interests us as a building material when *applied as artificial stone*, so reinforced concrete only begins to assume characteristics and to reveal possibilities of its own when it is applied as artificial wood.

We have seen with what analogous mode of design artificial wood claims sympathy. What is the mode to which we may reasonably look for guidance in designing structures of artificial stone ? The difference between stone and artificial stone is slight, but there is a difference, and it is well that we should give it full recognition and examine its bearing not upon the *rationale* of design but upon its technical possibility. We know that artificial stone is no very new material. The coarser kind which is known as concrete is fairly recent, but the finer kind, known as Roman cement, or perhaps more familiarly as stucco, is older. It should be clearly grasped that the difference between concrete and stucco is a difference in fineness only ; the obvious fact that the coarser material is given burdens to carry which the more delicate leaves for a brick wall to take over is an accident, a mere matter of degree. We may say, if it is thought better, that concrete contains the lumps of supporting matter within itself, while where stucco is used they are arranged separately in juxtaposition. The important thing is that stucco has long been subjected to the harmonizing and ennobling influence of architectural design, and has attained to a status, a physiognomy of its own, which is as soundly established as that of any other material. It is impossible not to recognize the consummate beauty of Regency stucco design ; it is impossible to deny

its autonomy, its success in achieving an expression which is not only beautiful in the abstract but beautiful also *in terms of artificial stone*. Clearly the mode of manufacture has been most conscientiously studied in those flat projecting faces, those bands and panels, those spare pilasters, all that smooth and concise architecture whose ornamentation is enclosed within a medallion or a tympanum instead of straying hither and thither as a mason's chisel strays over happy acres of crisply penetrable stone. Now, in referring to this point I would not be understood to say that we should think more highly of this fine legacy of late Georgian days because of the aptness with which its material is used. What I am, however, anxious to point out is that here is an admirably logical method of composition in which a set of technical problems have been solved that corresponds to those which the artificial stone bridge presents to us.

And having pointed to this exquisite solution I must end my brief survey of materials that have been called new, though in truth they are little newer than the scroll-backed couch or the novels of Jane Austen. They have all been grouped together and treated under the heading of temporary construction. It will be remarked, however, that between iron and artificial wood on the one hand, and artificial stone on the other, there is a wide difference in power of endurance. There is a still wider difference between the modes of construction proper to each, for artificial stone is, as its name implies, disposed in a manner similar to that which we habitually adopt for stone itself, while the other materials are frankly temporary, and the form into which they are worked are temporary too. We do not, however, know enough about artificial stone to fix its degree of permanence with any accuracy. We know its strength and we know that where this strength is but little taxed it has maintained itself for

many centuries ; that is all. But one thing is certain, that neither its strength nor its permanence can equal the strength and permanence of natural stone, whose strength is the strength of earthquakes and whose permanence is as that of the hills and mountains.



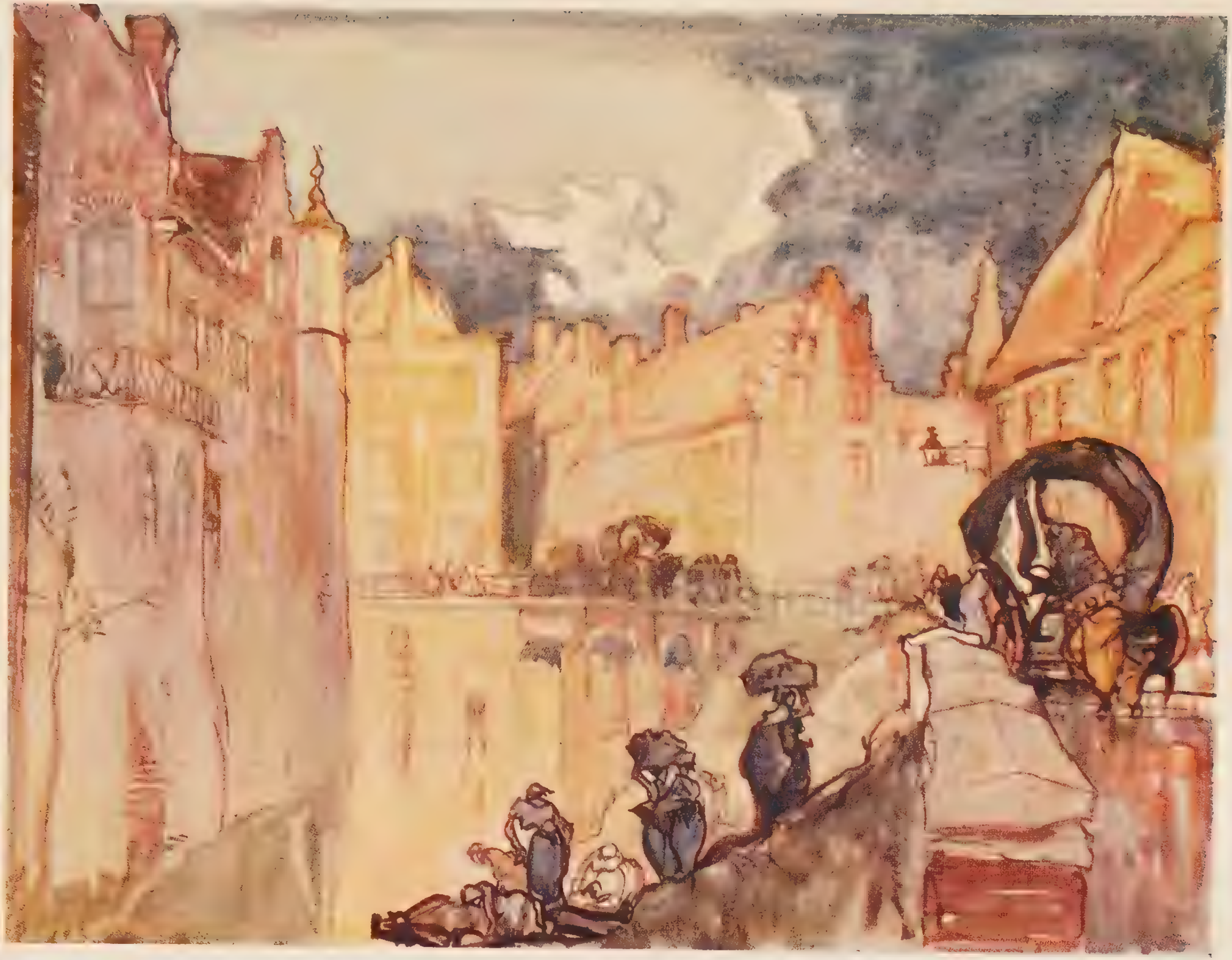
CHAPTER VII

§ 1

"BEAUTIFUL objects as such," says K. C. F. Krause, whose writings on æsthetics are too little read in our days, "must be independent of all external circumstances. Their beauty such as it is must not be determined by something outside them, but its origin must be sought within them and justified by their own intrinsic laws." That is the proper spirit in which to deliver judgment, and we have seen that in passing from the study of useful form to that of pure form we shall be entering that province of our subject in which judgment between æsthetic right and wrong becomes our duty. Did not Mr. Walkley, himself the most unassuming as well as the wittiest of commentators, somewhat wistfully complain the other day that this judgment was being less and less demanded of the modern critic? "It is," he admitted, "rather lonely work being *vox clamantis in deserto*." Alas, that there should be such a desert at all is a calamity

which perverted and fallacious criticism cannot have done more to bring about than feeble-minded and entirely colourless criticism. The task of æsthetic judgment is one from which no escape is possible in any age, but least of all in our own. There are matters connected with the architecture of bridges which we may happily leave to other judgments and other courts, but the difference between beauty and ugliness is one of which no one among us is suffered to plead ignorance. Like the poor, it is always with us; from it there is no escape. It is well, therefore, that we should protect ourselves by allowing nothing to claim this judgment from us that is not susceptible of immediate and reasonable appraisal. We shall refuse a hearing *a priori* to the bridge that has been imperfectly thought out. If a bridge be completely conceived we may still detect in it offences against the laws of beauty and propriety, but these offences will be but minor flaws in an adequately fashioned thing. If it is not, if the thinking-out has been overtaken halfway by the process of execution, we shall have before us an object that can only confuse our issues and disturb our sense of æsthetic right and wrong.

"Right and wrong"—are we then going to speak of architectural beauty in the terms of morality? The terms are useful, for they help us to bear in mind more clearly the autonomous nature of formal beauty, a thing on its own, obedient, as we began the present chapter by remarking, to its own laws only, the laws of form. "Good form" is a phrase that contains more than the superficial meaning we are accustomed to read into it. The laws that govern manners and deportment are universal in their application, and their idiomatic connection with the world of visual shapes is not an accident of etymology. These laws it is that our bridge too must observe. It is necessary, therefore, that we should not be tempted (as the æsthetic judgment is so frequently



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tempted) to set up one law for the rich bridge and another for the poor, one for the English and one for the foreign, one for the synthetic and one for the continuous. We must not allow its parentage and connections to bias our discrimination, nor must we make allowances for inherited defects, or increase our severity where there is an unearned superiority to begin with.

But it will perhaps be retorted that in tracing the growth of the bridge to its origin we found that its human associations, its eloquence of human strength and weakness, of human faith and human faithlessness, lent it its chief interest in our eyes. It was noted that just as we look with greater affection upon our own offspring than upon other people's, so we must always be more keenly interested in the works of man than in those of nature, be they ever so beautiful. Precisely ; and it is just because a human being interests us so much more than a fish or a cabbage that we will establish courts of law in which to judge his actions, and appoint to this task some of the most highly cultured and respected members of the human race. The essential difference between a man and a cabbage is one which must influence the regard we give to either of these objects, and certainly in a large measure decide our course of action in respect to them. But once we undertake to judge a human creature we must bind our eyes with the kerchief that has been the emblem of Justice ever since she became revealed to mankind.

Now it is meet that our pronouncement upon the work of man should be formed with the same meticulous impartiality. Nay, it is a thousand times more important, and for this reason. Your ordinary judge is out to combat evil, to detect and punish the wrongdoer, to disclose and to weigh the bad in him, not the good. But if a crime were committed by the son of a famous and highly esteemed scientist or general,

shall we say, it would be—but only in very exceptional circumstances—pardonable for a judge to take into account the debt of gratitude which the nation owes to this man, and to spare the son in order that the father be not too deeply shamed. Or if the accused himself has shown evidence of quite unusual public spirit and courage of temper, the indictment might legitimately take some account of this, and the penalty be alleviated. But who would not think it a shameful, a crying injustice if a recognition of *merit* were influenced by such extraneous considerations? If, for example, a man were made a Fellow of the Royal Society because he had a brilliant father, or if the Hawthornden Prize were awarded to some one who had distinguished himself in medicine or the law? And in our business of æsthetic judgment we shall (let us at any rate hope) be concerned with the detecting of excellence rather than of defects; once a bridge is admitted to judgment we shall look first of all for what is good in it. And since we shall be bestowing the ultimate honour that it is in the power of man to bestow upon anyone or anything—the recognition of formal beauty, the badge of æsthetic excellence—it behoves us to be just and evenhanded beyond a shadow of suspicion.

Thus we may find, for instance, that a bridge was, like our Tower Bridge, designed by a prominent architect, Sir Horace Jones. Clearly we shall be no more entitled to think more highly of it for that reason than we should be entitled to revise our opinion of a bad picture upon learning that it was the work of a Titian or a van der Weijden, or to think any worse of a good one because we found that its author was a Royal Academician. Or the bridge may be the product of a novel and interesting collaboration between architect, sculptor and engineer, like Vauxhall Bridge or the Pont Alexandre at Paris. Or it may be a bridge famous in history for the battles that

have been fought around it, or, with profounder justification, if it be a nodal bridge, because of its centripetal magnetism, its life-giving power, its honourable record as a nation-builder. Indeed, the historical significance of a bridge may lie anywhere between the extremes of trivial but exceptional incident on the one hand (such as the exposing of the heads of executed noblemen on London Bridge, on the Karlsbrücke at Prague, and many more) and of incalculable creative potency on the other. But gruesome as the story attaching to the one may seem to us, important as the other kind of bridge, of which London Bridge is an example, may be found from a wider angle of view, these matters have no connection whatever with the process of æsthetic judgment.

Again, the bridge may be a reproduction of some other, famed for its beauty rather than its prominence in history, or it may play a subtle or unskilful variation upon the original theme furnished by some such bridge, as the bridge at Chatsworth is a variation upon a design by Palladio. Whatever we may think of the original in such a case as this, we should certainly be careful not to read any of its virtues into its successor, nor should we think it ill in the later bridge that it has learnt something from the earlier, for if that learning has been wrongly acquired or ill digested we shall find enough evidences of intrinsic failure in our examination of the fabric itself, no matter how impartial. When a plea of this kind is advanced by a bridge it is enough that the plea be irrelevant; it does not much count whether it be true or false. Thus if we were examining a man for a degree in law it would not help him to tell us that his father was a coalowner; and had he told us so we should not disqualify him on finding the statement untrue.

While, however, it is in finding out the good that we have least excuse for relaxing the strictness of our judgment, it

is in the detecting of faults and shortcomings that this strictness will be most seriously imperilled. It is a more heinous offence to give a bridge more than its due than it is to palliate its misdemeanours, but the temptation to lenience is one that is unfortunately reinforced by all that is finest in our moral nature. Especially is this true in the humanitarian age in which we live. After a century of social reform we look upon a criminal as some one who should be succoured rather than reprimanded, and with the warmest anxiety we search for signs of physical and moral enfeeblement that will give us an excuse for putting him to bed instead of into jail. We would do anything rather than kill him, and if we do not succeed in curing him it is not for want of trying. And even in the few cases where severe punishment cannot be avoided we do our best to exonerate in the public eye whom we thus punish. Thanks to the courage and enterprise of modern scientists we are now able to blame his parents and grandparents, his wet-nurse, his baker, his milkman, his schoolmaster, his newspaper-editor, his employer, his doctor, his wife, his tax collector, his district surveyor—in fact we blame anyone except the accused himself for the evil that he has done. He is (we solicitously inform him) a creature of heredity and of social conditions, he cannot help what he is; in short, he is not what he is.

While I am writing the American press has been swelled to inundation for some weeks with the story of a particularly hideous and disgusting murder, and as detail was added to detail, and horror to horror, the cry of the psychologists went up with increasing loudness that the authors of the crime were not to blame, that their actions were inspired by ideas or sets of ideas which they had imbibed from outside, by motives and desires that had assumed control of their faculties against their will. And in this campaign they were seconded

by a vast array of entirely esoteric technical evidence, the unmentionable legions of modern psychiatry. Now it is not my task in this survey to speak against the attacks that are made every day upon the principle of human responsibility, but it is my bounden duty to insist upon the principle of responsibility in art. Without æsthetic responsibility there can be no æsthetic judgment, just as without moral responsibility there can be no prisons and scaffolds, but only hospitals and asylums, and a benevolent vivisection of human souls.

The great Taine is reported to have spent three years in the study of medicine as a preparation for his history of English literature. Is it to be wondered at that in another of his works he compares Carlyle to a mastodon and refers to him as *une fortune zoologique?* For myself, I have thought of Carlyle as many things, but I have never thought of him as a fascinating animal specimen that might be coveted by the Directors of the Zoological Society, nor have I ever been moved to liken the human mind to a cabbage, for that is what Taine means when he writes of the "vegetation of the spirit." But in examining the æsthetic merit of a work of art we must not compare ourselves to naturalists or even market gardeners; we shall not be as physicians charged to heal the sick and the halt; still less shall we be psychiatrists translating intelligible good and evil into unintelligible chemical formulæ. We shall be judges, and must concern ourselves with the ideas of beauty and ugliness and nothing else, and our verdict must be forthright and unequivocal. To this end we must have no truck with irrelevant theories, we must close our ears to the insinuating advocates of heredity and environment, we must brook no shifting of the responsibility upon other shoulders. For work of art and human being alike now require to be looked upon as active agencies of good or ill, and a bad bridge across one of our streams or streets may be a direct source of squalor

and deformity; it may surround itself with a poisonous, blighted area of ugliness, foully transmitting its disease to all that touches it, nay, to all that suffers it polluted look. And where there is such an influence who would be blind enough to overlook it, or foolish enough to belittle it, or culpable enough to pass it by in silence?

§ 2

The purpose of a bridge is to cross an obstacle. At the same time it is so built as to permit of the passage of water and of boats, small or large: in other words, it is pierced with openings. It must inevitably become an obstacle itself; but if it were not thus pierced it would be an impassable obstacle, and therefore not a bridge. Now a fine building is also hollowed out inside, but that inside, which is always at least as beautiful as the outside, represents the true usefulness of the building. The usefulness of the bridge, on the other hand, lies in its roadway, and the user of the bridge who follows this roadway is aware of no architectural beauty whatever in the structure. The bridge is a two-faced creature, and though you may see both of its faces combined in a sidelong view, you cannot catch the full glance of one of them without suffering it to obscure the other. Now the name of one face is Use, and that of the other is Beauty. By whom is this second and comelier one discernible?

Not in any way by those who are gazing at the first. The beauty of the bridge is disclosed only to those who approach it upon the water or along the banks of the water; it is a beauty unwillingly granted them, perhaps, though granted to none other; for it is the primary and deliberate function of a bridge to cross a stream, and to allow that stream to

continue its progress is only a secondary and incidental function imposed by circumstances. Out of this secondary function the whole beauty of the bridge, the power or delicacy of its piers, the sweep of its arches and the magic glimpses framed within them, the close and reasoned disposition of its masonry, the crowning pressure of cornice and parapet, are mysteriously wrought. You may use a cathedral or a council-chamber as it was meant to be used, and all the while take pleasure in the beauty of the building; but to see the beauty of Waterloo Bridge Mr. Brangwyn had to climb into a barge, the late M. Emile Claus must loiter about the embankment some hundred yards away, while Mr. C. R. W. Nevinson was driven to take an expensive room high up in the Savoy Hotel.

A bridge may, therefore, be likened (shall we say ?) to a sword to which its maker desires to give all the decorative charm it is in his power to bestow. He is limited in the accomplishment of this desire by the necessity of keeping the strict usefulness of the sword unimpaired. With the blade, therefore, he cannot interfere very much; its outline must remain long, flat and straight, its thickness slight and uniform. But in the handle and guard he may fairly let his fancy play. He may carve them with all manner of delicate devices, encrust them with threads of gold and silver, set them with precious stones of many hues. Now observe what happens when this sword is examined by its owner. At first, we will assume, he has no need to use it. He stands away from it. The sword rests against a chair, the long blade concealed in its sheath, the haft projecting and showing itself to the best advantage. No sooner does he pick it up, however, than this part, grasped firmly within his hand, ceases to be visible, while the blade issues from its sheath and at once proclaims the function of the weapon. Precisely the same thing happens in a bridge. Stand fifty yards down the stream and you cannot

see the road, while you have a full view of the piers that support the road and of the arches that allow the water to proceed beneath it. Walk across the bridge and all you see is a road, except that it is bounded on each side by empty space instead of fields and hedges, houses and shops.

This division it is that, as suggested in the preface to this essay, made the bridge so suitable a subject for the study of pure form. The subject is one thing and the form another, and in examining either of these things its counterpart is not likely to obtrude itself upon our attention as in so many among the other works of man. In deciding whether a thing is beautiful or not how often are we not incommoded with that other question about its purpose! It will trouble us but little here. The task of discovering the elements of beauty in bridge-building is therefore considerably simplified. We know that this beauty has nothing to do with the use for which the bridge is intended. Simple as this truth may seem, it is yet one which has inspired not only astonishment but sorrow also. A man who was told that the house he was building himself (at considerable expense) would charm and delight everybody else, while remaining invisible to him, would probably feel a good deal of disappointment. Yet even this supposition holds an element of truth, for it may be said of all things that we cannot at the same time properly use and fully enjoy them. We must do either the one or the other, and if we choose to use them we must leave the enjoyment of them to some one else.

It is not always pleasant to perform this act of selflessness. It seemed very unattractive to the Master of St. John's College, Cambridge, when his College decided to replace the old wooden bridge with a new one built of stone. In his trouble he consulted Sir Christopher Wren, whose opinions on architecture I have had more than one opportunity of quoting. "You

need not," replied Wren, " be solicitous that the bridge should appear fine to the river and the bargemen." Indeed, what was the bargeman compared to the Master of a Cambridge College and his Fellows, and what right had he to claim for himself the most delightful aspect of the bridge about to be put up by these? No, no, says Wren, " it is enough if the arches give passage to boats and floods, and be firmly built upon good foundations and with good materials." But cannot something more be done, something that will positively embellish the bridge to its learned owners? For merely to reflect upon the æsthetic penury of the substructure cannot give anyone much satisfaction. Indeed, this too may be done; " you have only to take care," writes obliging and resourceful Sir Christopher, " of a handsome balustrade, upon the piers of which, for ornament to the walks, you may set urns, pyramids or statues, even what your hearts or benefactions will reach." But urns and pyramids are not an integral part of bridge design, and, do what you will, it is not for Sir Christopher Wren nor for anyone else to repeal the law by which a bridge must turn away its face from its daily labour, and look out idly upon the stream.

Urns and pyramids indeed! Let us say nothing against these charming adjuncts of the architectural toilette; they are more in their place on the parapet of a bridge than on the roof of a building. But the bridge is something else, and its beauty is another kind of beauty. It is a unit in the great concourse of visual forms that we see all about us, marshalled throughout the universe according to a law that none shall disobey or belittle upon penalty of death. A law of order, this, of sequence, of coherence, a law which is similar to that governing that succession of sounds which we call music, and which therefore has earned the name of music of the spheres. A law which sees the ultimate ideal of the artist in his admission

that, to quote Heylin's admirable words, " the great body of the world, like the body of man, though it have many parts and members, is but one body only." It is the law of creation itself, and who will dispute that it is the same which was at once enacted and fulfilled when the Maker rested from His work and behold, it was very good?

§ 3

Having detached the idea of pure form from that of subject, it still remains to free it from the much more intricate entanglement in which it is united with the idea of useful form. We have learnt that to ask the question, " *What* is the bridge doing ? " is to advance not one step further towards the appreciation of its beauty, but rather to delay our progress thither. It is still possible to ask, however, " *How* does the bridge perform its task ? " Is there any connection between this inquiry and that other which we are now pursuing into the beauty of its form ?

This is what the adherents of what Mr. Geoffrey Scott has called the structural fallacy would have us believe. According to them a building, if not beautiful precisely to the extent to which it expresses its structure, is at any rate made more beautiful where it allows its forms to be narrowly governed by the laws of structure. They do not say that the laws of structure are synonymous with the laws of beautiful form, but they assert that a conspicuous submission to these laws is in itself productive of beauty, and gives the bridge in which it is manifested a clear æsthetic pre-eminence. Conversely (and it is here that they are able to work the most mischief) they will have it that no bridge that does not bear on its face the whole truth of its construction can have any

claim to be called beautiful at all. They do not deny that other kinds of beauty may be added in other things, but this kind, the kind that is the proper and unexpected reward of structural frankness, is foremost among all qualities of form, and without it all others are null and void. These others, it may be added, they claim that they are perfectly competent to appreciate, but only on condition that the beauty of structural frankness be first observable.

Perhaps this line of thought may be illustrated by means of a recent example. A design for the new Lambeth Bridge by Sir Reginald Blomfield, R.A., was recently hung at the Academy. The publication of this design was very welcome ; it has always been highly desirable that the public should know upon what kind of structures its money is being expended. The design for Lambeth Bridge was, though not exactly inspired, a competent and altogether unobjectionable production, except in one point. Its central carriage-way was shown supported on steel arches, while its footpaths and parapets were carried by reinforced concrete arches, faced with a traditional design in Portland stone. This discrepancy is open to criticism along the lines which will be laid down in greater detail in the next chapter, for while the bridge clothes itself in the prevalent urban garb where it is seen from the town, it disdains to pay a similar respect to the River Thames and those who use that important thoroughfare, which after all is not, as many suppose, to be looked upon as a convenient natural sewer but rather as the great ventricular artery of our metropolis, an object of beauty in itself. The criticisms that appeared in the press took no notice of this curiously divided attitude. Their objection was founded on the concealment of the structural steel and concrete behind a mask of stone. The charge brought against the design was not one of duality of æsthetic orientation, but of foppery and frippery

and untruthful display. If these critics had stopped to remember that most men wear a certain amount of flesh upon their bones, and—what is more—favour the concealment of even a quite generous layer of this flesh beneath garments of arbitrary shape, they would not have surrendered so easily to the structural fallacy in bridge architecture.

The sartorial metaphor leads us naturally to the yet more deplorable fallacy which attaches a supreme importance to material. There are critics who, not content with asking, *How* was this bridge made ? how does it work ? go on to demand *of what* it is made. One of the most distinguished of our writers on art has lately put this attitude in a nutshell. According to him the essential requirement of architectural design is that, to resume the metaphor, *the coat should be cut according to the cloth*. This homely saying reversed, cries the writer, would mean the same as putting the cart before the horse ! But obviously the first thing to be observed of his rule is that, whatever may be its relevance in architectural design, its general application to sartorial design would result in the most abject appearance of barbarism. I have often had the pleasure of meeting this critic, and it is my hope to meet him often again, but I have never yet seen him wear clothes that did not fully yet discreetly proclaim the fact that in them the cloth had been cut according to the coat. And if I ever do meet him attired according to his own rule I shall conclude (rightly, as I believe) that he has lost either his money or his sense of personal dignity. Indeed, to be able to cut the cloth according to the coat is one of the prime objects of civilized society, and to renounce this object is to renounce civilization itself.

This insistence upon structural frankness has one point, and one only, that can justify its intrusion into an æsthetical discussion. It is possible to argue that much of the crudity

of such structural metal-work as is exposed to the view may be the direct outcome of a generally accepted policy of concealment, which is not, it may be urged, productive of that sense of responsibility and confident independence of expression with which our old traditional materials were employed. But that this is a hollow argument may be seen by referring not only to the beauty of the human skeleton, but to the infinite care for logical comeliness of form with which the beams of a wooden ship, or the framework of an old roof or spire, are put together. It is surely not necessary to walk abroad naked in the market-place in order to cultivate the essentials of bodily beauty. There is not the slightest reason why even metal structures should not be made beautiful to look at, though there may be occasions where the proprieties of urban civilization require that their interstices shall not be left bare for any fool to look through. So much for what is perhaps the most plausible argument of the structural fallacy.

The fallacy itself is of course contemporaneous with the industrial age which has added so much to the materials and processes of human industry. About 1830, for instance, it became a common thing for cabinet-makers to put marble tops to their tables, sideboards and similar pieces of furniture. And once you introduced a slab of marble it was difficult to raise any objection to slate, which was considerably cheaper; moreover, a little later cast-iron began to be manufactured upon a growing scale, and it did not take long before heavy sheets of this material were also used for the same purpose. Bookcases, let us say, would be built of slate and cast-iron indifferently, or of both together. The native qualities of materials were no longer manifest as they had been once, and the more fastidious began to scent danger. What if one material should be tempted to ape some other? they were constrained to ask themselves. Voluminous essays were

written inquiring into the limitations of the new materials and predicting their effect upon architectural design. Some were sanguine enough to picture the almost complete iron house, or at any rate a house in which the roof was covered with iron, while floors, sashes, doors, blinds, shutters, porticoes and other essential parts were manufactured of the same material. But all the time—and I would ask my readers to take special note of this fact—all the time iron bridges of very charming design were being built at many places throughout the country as a matter of course. The manufacture of iron had, though it was still young, emerged from its infancy; the first iron wheel had been made fifty years earlier; and no speculation was necessary here as to whether iron might or might not be employed, any more than it was necessary with balconies, firegrates or table-knives.

That the clouds of barren casuistry which shed their gloom upon these discussions contained in themselves the seeds of so-called structural fallacy there can be no doubt at all. Its adherents have usually been as eloquent as their artistic productions have been deplorable, and in a period when words have largely taken the place of action they have indeed met with some measure of applause. There is no harm, however, in the doctrine when it merely sets out to discourage a definite simulation of one thing by another, against the "I am not what I am." But then it will not be an æsthetic judgment, it will not discourage such a simulation on æsthetic grounds. If it does all this it is overstepping its natural boundaries; the offence of simulation is an offence against honesty and common sense, not against beauty of form, and the structural doctrine only becomes a fallacy when it aspires to a voice in the expression of an æsthetic judgment.

And what shall we say of it when it demands not only that the "I am" should be free from undue equivocation, but that

it should be blazoned exhaustively, insolently, and without the smallest restraint, from every feature, should proclaim itself from every point of view, should pursue the spectator with an avalanche of unbeseeming self-disclosure, as it has more than once been betrayed into demanding? Surely it can then only be said to render the cause of civilization a very grave disservice indeed. For one of the principal effects of civilization is the gradual doing away with violence and effort, or at any rate with the outward signs of these disturbing factors. Whistler's epigram about painting is applicable to most other branches of human activity; it has become a commonplace to quote Mme. de Sévigné's apology for the length of her letter as embodying a fundamental law of literary composition. Our ultimate object now in every art, in the plastic arts, in poetry, in music, histrionics and every other, is to achieve the apparently effortless, the sublimely fluent, the noble charm of spontaneity. And what is it that requires effort in any art except the limitations of the material in which we work? When your pianist struggles over a difficult passage he is trying to conquer the limitations of the mechanical agencies of finger-joint and hammer and key by whose means he designs to produce his effect upon his hearers, but not till he has completed that conquest, and at the price of untold effort removed all signs of it from his performance, does this performance become tolerable to our modern senses.

The same is true in bridge architecture. We no longer want to see our engineer openly wrestling with well-nigh insuperable forces that strive to break up his arches, to send his handiwork floating down the stream. We expect him to fight his battles in his drawing office and not before our eyes. We of the twentieth century are, after all, the children of the eighteenth and nineteenth, and these things have ceased to interest us. In Elizabethan England and in Asia of to-day

it is nothing for a musician to spend the first half of the time set apart for a performance tuning up his instruments, but though we do not object to Mr. Arnold Dolmetsch doing the same because we go to his recitals for an evocation of the past, we would consider such a practice highly impertinent on the ordinary concert platform. It is no less impertinent in modern architecture, and where a great mechanical effort is necessary, and this effort is expressed in the members of the framed structure, it is as well that these should be hidden from our view. Mere effort does not in the least excite the curiosity of the normal individual.

We have supposed up till now that the effort was necessary, that it was due to the limitations of the material in which we work. What shall we say of a superfluous effort, of one which is dictated by no visible necessity at all? If I may resume the musical simile, what should we say to a musician who with wild and determined gestures and after three or four false starts proceeded, while mopping the perspiration from his brow, to play a trivial five-finger exercise? Would he not be greeted with shrieks of derision? And yet this is what many of our bridges appear to do, and that without eliciting so much as an honest and fearless reproof. I refer in especial to the kind of *through bridge* which is surmounted by a high-level arch. Examples of this kind of bridge are the bridge over the Rhine at Bonn and the Viaduc d'Austerlitz in Paris. London, I am proud to note, has so far resisted the critical enthusiasm of which such works are begotten, though M. Max Ende, a French engineer, once tried to present us with one. The best that one can say about such a bridge is that it shows symptoms that are much akin to those of hydrophobia. It is as fixed in its determination not to approach the water as any sufferer from this once irremediable complaint, and it exhibits the same unreasonable and exaggerated physical

activity. A bridge such as the Viaduc d'Austerlitz seems to have made up its mind to clear the water at a single jump, no matter what effort was required to do this, or how foolish it might look in the performance of such a triumph of inanity.

Now in the old permanent bridge of masonry a wide span and a high arch might be awkward and lack every element of graceful motion, but the awkwardness was never gratuitous. Moreover, the awkwardness was not limited to the arch, but was inevitably shared by the road itself, and so put an effectual check on any temptation to long-distance jumping that might have been experienced by a vain and thoughtless builder. In the Austerlitz type of bridge the roadway does not join in the leap into mid-air, it is torn away from the arch and hangs outstretched many yards below. Surely this dissociation can only make the strenuous behaviour of the arch look all the more foolish, for there is no room in a bridge of this kind for the supposition that headway might be required for passing ships. We may liken this form of arch to a man who has to carry a sack of potatoes over a stile, and who, instead of climbing over the stile with his sack across his shoulder, decides that he must on no account touch the stile with any part of his body. He fears, however, that if he jumps clean over with the sack he may spill his potatoes, and to avoid this he ties one end of a rope to the sack, and the other to his right foot, and takes a flying leap in such a manner that the suspended sack barely clears the stile.

I trust no reader will find this comparison exaggerated. The arch of a bridge has a burden to carry, and it is only reasonable to expect any leaps it may take to be so short that the burden shall not be imperilled, and need not be left to hang at a lower and safer level. Nor must this criticism be understood to apply to suspension bridges, where the point of support is high, and the supporting members come gradually

down from thence towards the level of the roadway. And it should be noted that there is an intermediate type in which the roadway also rises towards the centre of the span, though not to the same height of the arch. The iron footbridge over the Ouse at Bedford is an example of this type. The apparent gratuitousness of the effort is here diminished exactly to the extent that the roadway conforms to the curvature of the arch.

But if we do not (to sum up) wish to see a great effort of structure made without visible justification, nor indeed care to have it revealed to us in full even when such justification is present, it does not follow that the members need to be hidden with the cynical gesture of despair that some of our moderns affect. The current of thought that I may perhaps label the inverted structural fallacy has but little bearing upon bridge architecture, and I only propose to refer to it quite briefly. Since it has become impracticable to exhibit the whole truth of structure, so runs its grim argument, those covering forms that are visible to the eye will be less guilty of dissimulation if they exhibit an apparent structural impossibility; to quote the words used by a Dutch architect, Dr. D. F. Slothouwer, at a lecture recently given in London, "the most illogical brick construction is the most honest, because it clearly shows that it cannot exist by itself." We might apply a similar argument to the theory of dress, and say that if you wrap your trousers round your neck they will not appear to claim that they are supporting the upper part of your body. What is the intellectural or moral origin of such a theory of design as this? Must it not be said of construction as of a human action that the greater its excellence the less we should trouble about making it public? Is it not justifiable to suspect the sincerity of those who insist upon telling everybody of the good deeds they have done? These are they who are concerned not so much with good

deeds as with making broad their phylacteries and enlarging the borders of their garments. No, it is an ill deed rather than a good one that secretly goads its doer into confession, and it is probable that a builder who is concerned with nothing so much as the full exposure of his structural members has something on his conscience of which he would fain rid himself. The adherent of the inverted structural fallacy may perhaps best be likened to a man who has killed his wife, and who, being through some defect of speech quite unable to pronounce the correct word (if there be one), seeks to make peace with his soul by loudly proclaiming himself a matricide.

§ 4

Mr. A. Trystan Edwards, in his work entitled *The Things Which are Seen*, has formulated a grammar of design in which the various aspects of formal beauty are grouped under three heads. The first, the principle of number, has for its chief purpose the establishing of the example which is being studied as a complete and self-containing whole. The second, that of punctuation, concerns the definition of the extremities of this complete whole ; it is, in a manner of speaking, only a quality of firmness and emphasis added to the first. In the third, however, new and more expansive vistas are disclosed. Once you have established an object as a unity (which may embrace a multiplicity of minor parts) and not a scatter of things—least of all a duality, which is " the very soul of disunion "—and once you have signified quite clearly where this object begins and ends, you have practically exhausted the possibilities of the first two concepts. The canons of number and punctuation are satisfied, and you can do no more. You cannot go on unifying a unity or punctuating its

extremities beyond a reasonable limit. But the third principle, that of inflexion, has no such natural limits. " When," says Mr. Edwards, " one examines the means whereby two or more objects can have a resemblance to one another and yet maintain an individuality of their own, one is burrowing at the roots not only of design but of thought itself." And who would measure to what depth and girth the roots of thought extend ?

So much more potent and instructive is this principle of inflexion that I propose to deal with the others only in passing. There are but two ways, for example, in which the canon of number may be violated in bridge architecture. It may be violated in a horizontal direction when the bridge has a central pier, and in a vertical direction when it is composed of superimposed tiers of arches. Of the first kind there is a number of lesser known examples in which the offence is crudely manifest ; Giral's bridge at Villeneuve-lez-Maguelonne, a bridge of some merits in other points, commits it, as does the bridge over the Rhone at Geneva, Brunel's railway bridge over the Thames at Maidenhead, and several of the ugliest bridges on the upper part of this river. Many recent concrete bridges show the same defect ; the bridge over the River Tweed at Stobo is a conspicuous example. In many cases, however, the duality is resolved by the introduction of a central feature, such as a tower, a chapel, or a gateway, which dominates the two halves of the bridge and renders it, though still divisible in the centre, a much more nearly unified structure than it would be without such grouping, as we may call it, around a central and more conspicuous element.

The vertical kind of duality is occasionally found in viaducts and aqueducts ; the aqueduct at Bourgos, near Constantinople, built during the reign of Justinian, supplies a notorious example of this defect. It does, however, mitigate its failure

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by introducing a triple order of relief arches in all the piers, but as these arches have less than a quarter the span of the larger ones they are not able to correct the impression of duality to any extent. A much more satisfactory method of resolving this kind of duality, however, is shown in the bridges at Ispahan, Persia, and Zutphen, Holland, here pictured by Mr. Brangwyn. In both of these examples the elevation of the bridge is divided longitudinally into two tiers, but the upper and nether divisions have become so unequal in scale and importance that they no longer appear to compete with one another. Where two features differ in size to the extent here exhibited they can no more be called to account for offensive duality than can the shaft and capital of a column. But on the whole it will be found that the best structures of this kind, as *e.g.* the famous Pont du Gard and other Roman aqueducts (and also the finer modern ones, such as the French aqueduct at Roquefavour) are divided horizontally into three tiers of arches decreasing in size from the lower one upwards. In fact so widely is the solution of this problem of multiple tier design recognized as the aptest possible that nine people out of ten will, if asked to sketch a typical Roman aqueduct, indicate one with three series of arches superimposed in the order I have described.

Another kind of vertical duality, though much less pronounced, is to be noted in our own Vauxhall Bridge, whose high parapet has set so many foreign visitors guessing after the reason that caused it to be built. What concerns us here, however, is not the relation of this parapet to the size of the human figure, but the fact that its height is roughly equal to that of the midmost upright post in each spandril, and therefore to the average depth of the spandril. In other words, the area of each single spandril, which is the space between one-half of an arch and the deck of the bridge, is sufficiently

equal to the area of the rectangle comprised between the deck of the bridge and the upper rail of the parapet immediately above that spandril, to produce a very appreciable effect of duality. This is, of course, a form in which the offence is only seldom committed, for most bridges content themselves with a more rational parapet bearing the usual relation to the human element.

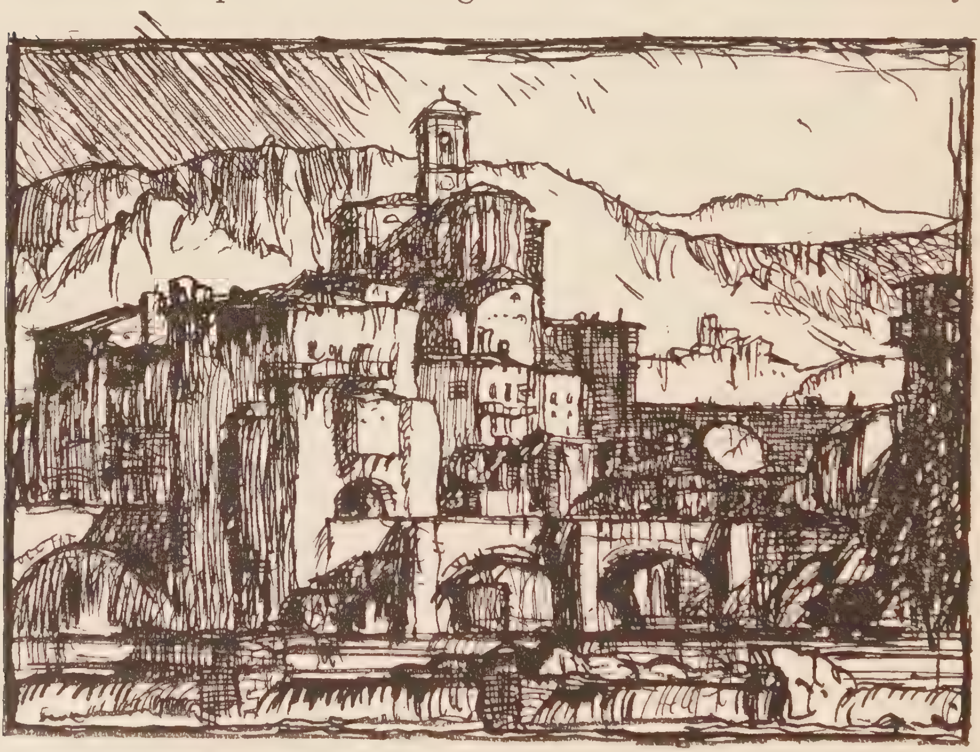
As for the canon of punctuation, there is only one feature in bridge design which we shall not be able to bring with equal justification under the control of the inflexional principle. It would, of course, be quite possible to study as such the punctuation of the ends of the bridge, or of the lower part of the piers, or of the crown or springing of the arch, but at each of these points the feature we should be studying would come in contact with another feature, whether internal or external to the bridge, and we shall find it more instructive to look at these junctions from the inflexional angle of view. But where the cutwaters break off, or the piers jut above the roadway, we shall find no such proximate element, for here the projecting feature stretches upward into the void. This is the place, then, in which to apply the principle of punctuation with the utmost care, nor shall we be surprised to find it so applied in nearly all the finest bridges in Europe. The punctuation of the upper part of the cutwater is among all the developments of subtle æsthetic form perhaps the most characteristic. We have seen that in the synthetic bridge the acute forward projection of the cutwater was often carried up nearly if not quite to the top of the parapet. This is done in the exquisite and world-renowned SS. Trinità Bridge at Florence, and the punctuation of the upper extremity of that projection is here of the happiest. But where the cutwater is terminated lower down such a rectangular head does not represent the best that can be done, and, without entering into the inflexional

relation between the cutwater and the pier behind it, I may point to the beautiful stepped conoids that reached such a high degree of perfection in French bridges, as may be seen in Mr. Brangwyn's drawing of the Pont Marie in Paris. From the cone to the pyramid is but a short distance, and from thence we may go on recalling the cone with an inverted triangle sliced off its face, the cone and ball, the broken column and ball (the bridge over the Loire at Tours has these), and finally the single and coupled column with their perfected organization of parts, pausing only where the punctuation of the pier begins to assume the civic impressiveness that is governed by its relation with the civic scene around it.

That is the proper field of the principle of inflexion which it still remains to investigate. We have seen that the principle may be applied to any feature of the bridge, and that the material with which it busies itself is the conjugation of that feature with another element, which, I suggested, might be " internal or external to the bridge." What exactly does this mean ? Are we to understand, then, that there are two kinds of inflexion ? Rather should we picture the principle of inflexion manifesting itself throughout a continuous series of visible forms, from the greatest imaginable to the smallest—from the giant world of Sirius and Betelgeuse to that other infinitesimal system which we are invited by modern science to imagine clasped within the atom. The inflexional forces at work are of course proportionate to the mass of each single body, but that does not mean that the greater and stronger do not suffer the influence of the lesser, and we may picture this ladder, this hierarchy of living forms, extending from microcosm to macrocosm, and obedient to this inflexional principle not in one direction only but in both. Now at any point of this scale or ladder we may put down our finger and fix a point of reference, just as we fix the middle point in a vocal

scale. On one side of this point will be the greater, the deeper; on the other will be the smaller and shriller. If we make the bridge this point of reference we shall have a similar division of higher and lower, of greater and smaller, but the greater will be outside the bridge, while the smaller will mostly form a part of its structure.

Hence we may now complete the distinction already foreshadowed, and speak of a dual aspect of the inflexional principle. In studying external inflexion we shall be looking outward, as it were, upon the river and bank, and upon the city that perhaps extends on each side; with the internal kind we shall turn our gaze inwards, and survey the relation between one part of the bridge and another. I need scarcely



point out which of these is most important, most extensive, most influential. For every possible error in internal inflexion there are obviously ten in the external; moreover, an error in the latter kind will be much more visible, will create an infinitely more disturbing incongruity, than one of internal inflexion. And no excellence of internal design can possibly outweigh a serious offence against the proprieties of external inflexion. It will be unnecessary, therefore, to make any excuses for proceeding at once to the more significant division, leaving the other, in the present survey at any rate, to take care of itself. For the relation of internal inflexion to external is the same that exists between home and foreign politics; and we all know that without a sound foreign policy a nation has little time to attend to its domestic affairs. It must first live at peace with its neighbours, and once it has learnt to do this it will not find it difficult to live at peace within itself, and to devise laws that will permit its citizens to lead useful and contented lives.

CHAPTER VIII

§ 1

INFLEXION is a principle, not a fact: a principle which can be extended, elaborated and fortified almost indefinitely. There is no such thing as perfect compliance with it; there are various degrees of discrimination and degrees of compliance. But these degrees observe a clearly visible progression from the lower to the higher as a civilization matures. Am I, then, about to introduce the historical element into this outline of the æsthetic of bridges after warning the reader that history has nothing to do with æsthetic judgment? Fortunately, this will by no means be necessary. In tracing some of the typical stages in the development of social organization we shall not need to cast a backward glance at its history, for these several stages are still exemplified to-day and are to be found side by side with the latest of them, the twentieth-century metropolis. We have only, therefore,

to look about us at the present time to see the principle of inflexion applied with a varying strictness, whose adequacy it will be part of our task to estimate. The degree of this strictness is of course determined by the social complexity of the surrounding picture. For our present purpose it will be enough if we recognize two kinds of picture, that afforded by town and country respectively.

We have elsewhere traced the development of the urban bridge and noted how it was originally begotten by the great city-building prototype that was once a rural bridge, but a rural bridge upon which some magical spell had been pronounced, a rural bridge that by its position was elevated into a city-builder, a nation-builder, far above other bridges. The rural bridge, I need hardly add, stands below the urban in exacting adherence to the principle of inflexion, and it is well that we should glance at it for a moment before coming to the more highly civilized type. Only for a moment need we do this, since the greater includes the lesser, and all that we shall learn about the urban bridge will apply in a restricted and fragmentary way to the rural. That it will thus apply, however, is true only of the *manner* of its inflexion ; it is not true of its *matter*. We must be careful to determine not only in what way the rural bridge may be inflected with its setting, but what this setting is.

It may be instructive to begin this inquiry by glancing at the direct ancestor of the rural bridge, a bridge which I may perhaps call the *natural*. Though it, too, exists in our own day, a humbler contemporary of the Forth and Hudson River Bridges, its origin is not so much a matter of history as of anthropology. It is to all appearances so integral a part of nature that it might well be surmised to be natural in the strictest connotation of the word, or, if not actually a product of geological or vegetable formation, the work of some tribe

of giant apes or beavers. I refer, of course, to the bridge spanning a lesser watercourse with a piece of stone or timber untouched by tools, or a larger one by means of the twisted stems of creepers stretched to form a suspended pathway. The process of differentiation between man and nature has here not yet begun ; you could, if you were to meet with such a bridge on an island, say, such as Robinson Crusoe's, not very safely conclude the presence of human beings to be definitely established thereby.

Now the rural bridge is to the natural what Hardy's Wessex is to the desolate scenes of Defoe's *Crusoe* or of his *Captain Singleton*. It has acquired human characteristics. Its setting is no longer the wilderness, but meadow and tilled field, and farms and villages are, if not in immediate juxtaposition, at least within sight. Its substance is no longer that of the forest undergrowth, but is homogeneous with the village itself. Yet the rich and exquisite formality of the urban bridge is absent ; there is no dispensable subtlety about its façades ; its arch is simply and broadly turned ; its cutwaters are there to guard it against whatever strength of current there may be, and their punctuation is seldom much thought of. For the rural bridge should not be confused with the Palladian or country gentleman's bridge, which is to the other what Chatsworth House or Kedleston is to the village public-house. The Palladian bridge is an offshoot of the urban bridge contracted in scale, just as the Japanese dwarf tree that you may keep in a flowerpot derives from the pine of the forest and echoes its forms in miniature. Its beauty is the beauty of the bucolic poetry of a Marvell or a Watteau ; it has nothing in common with the rural bridge proper except its size and the trees by whose foliage it is framed. Nor is it in any way legitimate except when it stands in the neighbourhood of a larger architectural unit such as an important country house,

of whose formality it is of course able to partake with delicious effect. But remove it from thence, plant it in the humble position now occupied by one of those rural bridges which every Englishman cherishes along with his favourite county or hamlet, and you will at once be struck by its complete inconsistency with the surrounding scene.

The road, the river, the tree at its edge, the hill beyond, all have their physiognomy, and the nearest farm or public-house no less, and it is in such company that the rural bridge comes into being and spends its modest but useful existence. It is with the colour and the forms of these surroundings that it is inflected. For, in addition to the inflexion of form which is pre-eminent, the correspondence of colour and material has of course also to be considered. All of these, if the bridge is to escape our censure, must accord with the corresponding elements in the human settlement of which the bridge is a part. What are we to say, then, of a concrete bridge in a place where neither stone nor stucco nor concrete itself are to be seen, but only mellow bricks and tiles, even though there be an admixture of flint, a touch of ironstone here and there? What of a bridge of bright red colour pushing itself into a village built entirely of grey freestone? As for the use of metal, which plays a not unimportant (and often admirable) part in urban architecture, in the design of rural bridges it should be adopted with much caution. Since they cannot often be referred to the background of rural architecture, metal bridges, where they are chosen for the country, may achieve a sort of inflexional consistency by looking to the stems and branches of trees rather than to the human dwelling for their cue. Especially is this possible in the suspension bridge, and a small bridge of this kind, smoothly and delicately swung, may form a very pleasing feature in a setting of trees and foliage. The little suspension bridge across the lake in

St. James's Park is not exactly a model to be closely followed, but it is only fair to say that at such a point its gentle curves are infinitely to be preferred to the barren rigidity of the metal girder types, for example.

The introduction of metal with its light and open forms, so often harshly angular in outline, is only an effect of a very common tendency to let the urban spirit assert itself too abruptly in the countryside. I have described the error of inflexion that would be committed if a Palladian bridge were put in the place of the typical rural bridge with no Palladian mansion to justify it. But this very mistake in a less elegant form is the chief source of ugliness and discord in our rural bridges. Just as there are people who are unable to doff their black coats and billycocks in the most remote of sylvan *milieux*, so there are engineers who can never forget that they learnt their trade in London or Manchester, even though they may be putting up a bridge by the untrodden bank of a Devon streamlet. Such a practice can only be condemned as a painful solecism, and its remedy is to be found in a careful study of inflexion in its bearing upon architectural design, and an equally careful study of the surrounding elements whose presence has to be visibly acknowledged in the bridge.

§ 2

There is one kind of bridge in which the claims of the immediate locality must be waived in favour of others more distant yet more authoritative. Along with the Palladian bridge comes another product of urban civilization, no longer an offshoot, perhaps, like the other, of the urban bridge, but rather a magnified version of the proper rural kind. The rural bridge derives its character from rural building ; its scale is

AQUEDUCT DI PORTA CARTARA, ASCOLI PICENO

the scale of this building, its materials are its own materials. Wherever a rural bridge exceeds this scale and supplements these materials we may be sure that it belongs to the other and later class. Its purpose is now no longer to unite bank with bank, road with road, house with house; instead it connects one hill, one mountain with another. Its scale is the scale of the mountain; the public-house, the whole village itself, now lie before its bouldery piers as at the bottom of a precipice, at the foot of an alp. Viaduct or aqueduct, roadway or canal, it is entirely alien to its setting in purpose as in formation, though not necessarily in its substance. The train that speeds along its dizzy ridge, the water that runs to quell the thirst of a far-off metropolis, have as little to do with the people below as though the one had never left its shed, or the other its mountain reservoir. The function takes its place in a national activity, the design becomes part of a landscape, and conforms with the larger unit against which unaided man must always appear intolerably small. Has not a mountain become symbolical of all that is huge, exaggerated, oppressive; does not its silent altitude challenge and excite the bravest of our kind to mortal combat among the clouds? No wonder the aqueducts of Segovia, of Ascoli Piceno, of the Gard Valley (not to speak of our own great viaducts like that at Pont-Cysylltau, so keenly admired by Sir Walter Scott) have thrilled generation upon generation of artists and poets, from a Jean Jacques to a Brangwyn!

To crown a great rock with a castle or a church, such as that of the Mont St. Michel, is a splendid feat enough, but greater still to rival the mountain itself with a structure raised up from its foot, to strike a path leading from one summit to another, and enduring two thousand years or more, while libraries burn and cities are buried in dust. And this aqueduct, being a part of the mountain and not of the village, an element

of urban civilization and not of the rural, has its own inflexional laws to obey. It should be urban in expression, but its urbanity should be cast in a heroic mould; it should be mingled with the grandeur of the mountains into whose vastness it has ventured. Indeed, its intrusion there constitutes a deliberate attack; it has something of the military about it; it is a work of brave and ambitious pioneering, it stands as an outpost of the civilized world. Like the settler labouring in a wild country it should overlay its innate urban balance with an armour of rustic strength. Without the urban centre beyond the range, and the consequent urban inflexion in its lines, it would be a freak, an impossibility; without the mountain on this side and that it would be a foolish trick, an exhibition of useless strength.

This last is a point which has evidently been overlooked by those who, like Lord Montagu of Beaulieu, would like to see a great viaduct to carry fast road traffic over London's tallest buildings. If London were situated in a deep valley or, better still, at the bottom of a precipitous ravine, such a scheme as this would not at once have to be condemned by every thoughtful person because of its utter disregard of the principle of inflexion.

§ 3

Let us begin our examination of the urban bridge with its prototype, which is the nodal bridge constructed in rural fashion before the town had yet become much more than an important village. As the town expands attempts are made to urbanize the bridge; that is to say, to inflect it, to make it conform with the urban scene which is springing up around it. The principal means by which this urbanization is effected is the building of houses on the bridge itself. We must remember that both banks of the river at this stage are lined

with houses, as are the canals of Bruges and Venice and as the Thames below Blackfriars is lined with warehouses. Here and there is an open space at the foot of a street running down to the river's bank. On the urbanized nodal bridge we shall often find this same distribution of buildings—the houses at the edge, the few open gaps between—exactly reproduced. We find them thus, for example, on Old London Bridge. There can be no doubt that this building-over with houses contributed very effectually to make the bridge fit into the general aspect of Elizabethan London with its overhanging gables and noisy, tortuous streets. It was the first step towards a completely understood urban inflexion.

By the time the first urban bridge came to be newly put up, the town had long since become changed, had itself become more definitely, more completely urbanized, and buildings on bridges are no longer tolerated as the streets are widened and the very banks of the river opened up at more and more frequent intervals, until we get the splendidly embanked rivers which are perhaps the chief beauty of many a modern capital. The very fact that a river is navigable and carries much traffic (conditions which, we know, can alone produce the nodal bridge) is of course apt to retard the process of opening up, and the Thames, the Elbe, the Tiber, are subjected to it long after such lesser waterways as the Arno at Florence, say, and Pisa. The complete open terrace could only supplant the warehouse and quay when much public wealth had been accumulated, and extensive docks constructed where ships might load and unload in greater safety their cargoes of increasing price.

As for the buildings on bridges, their survival was favoured by economic factors to which I need not here refer. Suffice it to say that as urban civilization prospered, they were mercilessly done away with; indeed on many bridges, as

on our own Blackfriars Bridge, they were forbidden by law. When the Pont Neuf in Paris was first built, cavities were left for the cellars of houses which it was intended to erect on the bridge, but fortunately Henry IV realized the inflexional anomaly of this plan, and following a prohibition issued by him the voids were promptly filled up. It must surely be agreed that wherever the great effort has been expended and the sacrifices made that are necessary for the clearing of warehouses and the building of a terrace embankment, there the erection of houses on a bridge is nothing less than an impropriety which can in no way be defended. The reservation is of importance, for the Bridge of Sighs and the Rialto are charming, but they belong more properly with such examples as our own Coutts Bridge in the Adelphi, or the bridge in New Scotland Yard, which connect buildings instead of open terraces. And yet suggestions for built-over bridges in great cities are continually made in dead earnest, London itself being no exception. The late Mr. T. E. Collcutt, the architect, once published a design for a Charing Cross Bridge which he showed thus built over, sumptuously enough it is true, but with the most complete disregard of the fine spaciousness of the surrounding picture. And at least once every three months the *Times* correspondence column contains a proposal from an eminent man (generally a member of the Bar or a dental surgeon) that our bridges should be made to carry blocks of flats, office-buildings, shops, hotels, music-halls and what not. It is sincerely to be hoped that our common sense at any rate will save us from committing such an outrage against the decencies of urban building. And there is another side to the picture. The weight of the houses on Old London Bridge by the beginning of the eighteenth century had so torn asunder the fabric that in many places a man's arm could be thrust into the clefts.

The matter of over-building is narrowly associated with the inflexional claims of the river generally in the design of bridges, and it will be well briefly to review those claims before coming to those of the urban community on its banks. The opening-up of bridge and bank alike is indeed the highest possible form of recognition which it is possible to extend to the significance of the river. It is as though some one who hitherto had been regarded as a humble but exceedingly useful servant had suddenly been found a prince in disguise, and had been elevated to a position of honour in the household, though not for a moment ceasing to perform his duties as formerly.

Deference to the singular beauty and nobility of the waterway is paid by the bridge also in several ways, and first of all in its approach. The principle that governs the whole behaviour of the bridge towards the river is that of the least possible interference. Now in order that it may not impose an unnecessary extent of masonry upon the river it is desirable that the approach of the bridge should be rectangular. Any intersection other than the rectangular is bound to lack inflexional propriety, and it is instructive to note that nearly all our bridges built before the nineteenth century will think nothing of demanding a bend or twist in the road so they can approach the river's brink looking the obstacle square in the face. There are sure to be some who will ascribe this practice to the technical difficulty of building obliquely. They are wrong. The building of oblique arches was successfully enough accomplished in the Pont Neuf, where they are of course inflected towards the island at which the two arms of the bridge meet ; besides, a skew arch may be made up of juxtaposed rings of masonry, each built at right angles to its axis, a combination which presents no special problems of structure whatever. No, the rectangular intersection is an

æsthetic device, a device of which Nash himself did not disdain to avail himself in the planning of Regent Street; and to apply it he not only turned his new street into a charming quadrant before it crossed Piccadilly, but gave it a much less attractive twist higher up that it might cross Oxford Street with the same dainty precision.

But let us follow this principle that limits the area of incidence in some of its other applications. It is equally to be observed in the forms that are given to the arches of a bridge. These arches may be placed for a moment in their proper position among the various apertures that are used in building, and that range from the narrow vertical slit of a window through which light and air are admitted (and that very sparsely) into the stairway of a Norman tower, to the flat arched culvert that carries a streamlet under a road or embankment. Next after the tall window there comes the ordinary door designed to the proportions of a human being walking upright. The door or gateway through which a carriage has to pass, which is considerably wider for its height, follows. Thus we come gradually to the still broader kind of arch used in bridge construction. As a civilization develops the span of these arches continues to grow wider and wider, while the piers grow fewer and fewer, until they vanish altogether and we reach the limit of expansion in the single arch. Such an arch was designed by Thomas Telford for London Bridge, but fortunately was not carried out—fortunately, because the regard thus paid to the waterway detracted quite unduly from that which was claimed with even greater force by the city itself.

This regard is expressed in the width of the bridge no less than the span of its arches, for the width of the bridge is the depth of the arch, and nothing is more damaging to the beauty of a river (and, indeed, to the ease and safety of its

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navigation) than the gloomy cavern that is formed beneath an arch of excessive depth. There is at the present time a short-sighted and reactionary tendency to give all bridges the full width of the road by which they are approached. This has never been done in the past; most often the road in crossing the river has, recognizing the fact that its crossing must reduce the free width of the waterway, voluntarily submitted itself, as by an act of courtesy, to a corresponding contraction. We have recently had an interesting illustration of the importance of this recognition of the presence of the natural way by the artificial. When the L.C.C. decided to widen Waterloo Bridge (by common consent a trifle narrow for modern traffic), they were soon enough reminded that such a widening could only be effected at the expense of the amenities of the river, for they were met at once by a counter-claim from the Port of London Authority that the bridge should be entirely rebuilt and arches of longer span substituted for the present ones. The retort was a perfectly natural one. If an arch is deepened it should be widened also, or it will soon cease to be an arch and will begin to resemble a tunnel.

For the characteristic proportions of a bridge arch it is only necessary to look at Mr. Brangwyn's drawings of the bridges at Durham or Assisi, or better still of the Roman Ponte di Quattro Capi, once the Pons Fabricius. Mr. Brangwyn and Piranesi resemble each other in that both have perceived and put on record this quality of amplitude in bridges, and expressed it in the beams of light that come pouring through the arch. Piranesi has only given the Pons Fabricius a secondary place in his etching of the Isola Tiberina, but he has shown these cones of light emerging from the low-browed Ponte Lucano and Ponte Salario, and illuminating with their full intensity the loftier sweep of the Ponte Molle arches. Here is a bridge indeed! And it is with bridges that we are

now concerned, and not with tunnels and sewers, no more than the port authorities are concerned with underground navigation.

Finally, the bridge can pay a yet subtler tribute to the waterway in the actual forms of its arches, piers and cutwaters. Thus on a tidal river, or any river where the level of the water is variable, the arches should always be so sprung that when the water is at high level, the aperture does not look as though it had unexpectedly been curtailed. Indeed, the appearance of the curve at the different states of the tide is of extreme importance in its design. Clearly the opening should present an agreeable outline, and combine agreeably with its reflection in the water, at whatever level this water may stand. Most of our recent bridges fall far short in this respect ; the arches of Westminster Bridge, for instance, are a very pleasant sight (for I fear much of the abuse directed against this bridge has been rather unintelligent) at high water, but become more and more ungainly as the tide runs out. At low water they straggle at a great height above the level of the Thames, in such a way that one would think the river had suddenly dried up and revealed a part of the structure that had no business to be seen. This is surely a very conspicuous lack of inflexion indeed, and it must be agreed that the bridge that shows its awareness of the various water-levels is infinitely to be preferred.

In Hawksmoor's design for Old Westminster Bridge there is a projecting band in the stonework of the pier at the level of high water and another at the low. This would appear no very difficult thing to do, and one of the best opportunities of indicating the upper of these two points is afforded by the breaking-off of the cutwater and the various punctuating devices that I have briefly described elsewhere. But even where the cutwater rises to the top of the bridge, there is no

reason why the necessary inflexion should not be introduced by diminishing this part a little just above high-water level, leaving a small projecting ledge, as in the beautiful SS. Trinità Bridge, whose arches are of course the model that inspired the present bridge at Westminster. But at Westminster such a ledge occurs not only at this point, whence the cast-iron arches are made to spring, but also a few feet higher up. Here it serves no inflexional purpose whatever, save the minor and extremely doubtful internal one of linking the exiguous pier to the projecting cutwater by means of a suitable transition.

It is not always necessary, however, to emphasize one of these levels with a break or projection, for the springing of the arch itself may supply the necessary point of reference. One need not be a mathematical expert to discover the precise point at which the curved line flows into the straight, whether the junction be marked by an angle or whether the vertical be normal to the curve at the meeting-point. The springing-line always suggests a definite vertical division, and for this reason (if for no other) we must altogether condemn a practice which has often been resorted to in building a bridge whose roadway rises towards the centre. If the arches of such a bridge are equal in span (which, indeed, it is better that they should not be) the same centering is often used for all of them, the necessary increase in height towards the middle being obtained by raising it higher from arch to arch, thus giving the arches what is known as a stilt, but a variable stilt. Now the eye is perfectly able to detect the discrepancy between the various springing-points, and this discrepancy, especially at a small distance above the water, constitutes a grave inflexional error. Obviously a bridge in which it is found has not taken sufficient account of the level of the stream.

Apart from this matter of level, however, there are other

opportunities of inflecting a bridge towards the river. There is the shape of the cutwater, for example, which may be subtly rounded in a thousand different ways to respond to the motion of the stream. Moreover, its forms, and those of the punctuating features that crown it, may allude to the waterway in directly illustrative fashion, and, hovering on the boundary that divides architecture from sculpture, take on a semi-nautical air. They may even go so far as to imitate the very shape of a boat, as in the exquisite bridge at Navilly sur Doubs, built by Gauthey at the end of the eighteenth century, in which the lines of prow and stern are translated into architectural terms of admirable strength and vivacity.

§ 4

The fullest application of the inflexional law is, of course, found when we come to relate the urban bridge to the city in which it stands, and to examine how its forms are dictated by the totality of its urban environment. The first question which meets us here is one whose answer at once determines the general outline of the bridge. We know that from the water's edge the ground generally rises with a gradual slope even in the flattest of countries. Is it the purpose of the bridge to connect the banks themselves, or the more elevated tracts behind them? To frame the answer to this question is not within the province of æsthetics, but it is necessary that any study of inflexion should take cognizance of the answer when it is given. For if the bridge is to connect the parts of the city which lie beyond and above the river's bank, it must intersect the buildings standing on this bank at a point perhaps halfway up their elevation. Obviously the most elementary observance of the inflexional law requires that this

point of contact should be properly expressed in the bridge and at the same time in the buildings themselves. Compare, for example, the two extremities of Waterloo Bridge. On the Surrey side the relation between bridge and buildings is not given the smallest recognition, and the roadway is engulfed somewhere at an arbitrary level between the upper stories of these. At the northern bridgehead, however, Somerset House on the one side, and the Lancaster Place Terrace on the other, express an adequate recognition of the roadway level which they repeat and extend with delightful effect in their respective river façades. Towards these the bridge on its part unfolds its abutments, helping to produce a unified architectural group which has few equals in London. At London Bridge the two extremes of observance and disregard may at the present moment be observed side by side. Opposite the Fishmongers' Hall, which (though on a smaller scale) follows the practice so well exemplified in Somerset House, a modern office-block designed by Sir John Burnet shoots up from the level of the river's bank without acknowledging in so much as a single line the passage of one of the most important thoroughfares in the metropolis over a bridge to which London has given its very name. If, on the other hand, the surrounding structures are required to recognize the incidence of the roadway level of the bridge, on the other hand the bridge itself should be made to recognize that of the bank. If, as in the examples just cited, the bridge passes over the bank to a point further up, it is important that the level of the lower bank be indicated somewhere in the general composition of the structure. Unfortunately, our two great metropolitan high-level bridges were built some time before the Embankment came into being, and the observation of this law cannot therefore be studied in them. Everybody must agree, however, that the two or three tiers of many

Roman aqueducts owe something of their singular beauty to the consistency with which they are related to the contours around them. In other examples, at Avignon or Montauban, for instance, the cutwaters are stopped at the level of the neighbouring bank. But an even less obvious expression than that will often be enough ; in one of Palladio's designs, where the roadway at the centre of the bridge is somewhat more elevated than on the bank, the lower of these levels is only echoed in the cornices that crown the niches hollowed out of the four piers, and that with perfect adequacy.

A great bridge that connects the banks themselves, however, must effect its junction with the bank with somewhat greater emphasis. The relation here is a more intimate one, and the finer and more highly organized the architecture of the bridge, the greater will be the care with which its abutments are developed into rounded wing and buttress, ramp and stair and watergate. We in London are especially fortunate in that we possess in Waterloo Bridge an example of the imaginative treatment of abutments that has seldom, if ever, been equalled. The criticism I have just made of it is a matter of chronology rather than of faulty design, and the boorish way in which the northernmost arch strides across the Embankment should be a warning to us rather than a source for complaint. The very tramway-tunnel sheds about it a genuine atmosphere of imaginative excitement, and in descending the steep and gloomy stairs from the level of Lancaster Place it should be remembered that they were never designed in relation to an important highway such as the present Embankment, but when they were first built led down (as their companions on the Surrey side do still) to water's edge or mud-flat, nothing more. And to this humbler inflexion who shall say that they do not admirably respond ?

It still remains to study the larger correspondence of the

bridge with the urban scene in general. The subject may be separated for convenience into three distinct aspects: first, the bridge must be built to a similar unit of scale; secondly, it must choose its architectural forms within the particular range that is observable in the city; thirdly, the substance of which it is made should answer in density, in colour, in its various social and economic associations, with that which predominates round about. This threefold aspect of the law of inflexion has, it will already have been gathered, become of infinitely greater importance since the industrial era (as it is called) has seen the speed of execution exceed the speed of conception. Whichever of the three we choose to examine, we shall have to be careful about admitting our modern subjects to judgment at all. What is to be said, for instance, of such a bridge as the Viaduc d'Austerlitz in Paris? Here is to all appearances a work that has had the utmost care lavished upon it. The giant steel arch, the roadway and parapet, the hinged junctions upon which it rests and the latticed rods from which it is suspended, all the parts that make up this bridge (but most of all the great terminal pylons in masonry, designed in the free exuberant manner so brilliantly taught at the Ecole des Beaux-Arts) do their best to achieve for it some recognition as a work of art, a work of æsthetic pretensions. And yet such recognition must be withheld. We cannot judge the Viaduc d'Austerlitz because in it the modern facility of construction has run on in front of the creative intelligence that cannot be hurried, no, not by anyone. The bridge is not "designed in full."

While the ease of construction was still undeveloped, and building proceeded at a slower pace, there was a natural limit to the things it could do. There is a limit to-day also, but it is infinitely further removed from what we may call the line of æsthetic safety. The need of a controlling intelligence

is therefore all the greater, and its absence should not be lightly spoken of. I need scarcely say that the Austerlitz kind of bridge, whose structural futility I have elsewhere compared to a form of hydrophobia, in addition heinously violates all three aspects of the canon of inflexion. Its scale is not the scale of the city, for the region into which the apparently meaningless arches soar is that of towers and spires, tokens of civic or religious supremacy. Its forms, which are dictated partly by the processes by which the steel is rolled and the concrete moulded, partly by a system of rigid economy in the disposition of bolt-holes and bolts, have not the slightest resemblance to the architectural forms by which it is surrounded. Its structure is open, whereas the structure of the town is solid, even the roofs, which are supported by a framework similar to that which supports the bridge, being made to conceal that framework rather than exhibit it to the view. Its substance, that is to say, naked metal or artificial wood (scarcely ever the vegetable kind), is used architecturally in subsidiary features only, such as porches, balconies or lamp-standards, none of which are germane to the bridge in scale.

This question of scale, which was placed first, has indeed to-day assumed a predominant place. We have already had occasion, earlier in this chapter, to note the existence of the magnified rural bridge. We have sought the scale of this bridge in hill and mountain rather than in cottage and field, but even where the land is level, the scale may assume these heroic proportions with considerable fitness provided they accord, as in the other place, with the totality of the landscape. The Forth Bridge is a justifiable example of a truly spacious work in a spacious setting. We have noted that in some towns the scale of the bridge naturally connects itself with the scale of the landscape rather than with that of the town; the town

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itself, in such a place, will necessarily be subordinate to the landscape. This cannot occur, however, in a capital which has sprung up around a nodal bridge, for in such a capital the urban element is always supreme. There can be no choice in London or Paris between town and landscape; the landscape simply does not exist. Ingenious, therefore, as is the bridge in which the structural members stand high above the roadway, it can have no place in cities such as these.

Another illustration of the importance of scale will be found in the qualified manner in which the steel and iron bridge had to be condemned. Iron has during the past few centuries become an integral part of urban architecture, and its use has in many cases been attended with the most enchanting results. To-day its application is steadily extending, but we have not yet seen an architect bold enough to make stone and other solid materials subservient to a visible metal framework in the design of a building. This would be all the more impossible because important buildings are erected in urban areas already densely built, in which such an attempt would at once stand condemned by the very laws of inflexion whose application to bridge design we are examining. But lesser pieces of ironwork of admirable design are to be found in all our towns where the eighteenth and early nineteenth centuries have done any notable amount of building, and along with these may be seen a number of truly exquisite cast-iron bridges. Being as humble in their position as they are excellent in design, they are unfortunately often overlooked. The Regent's Canal in London has three or four which are little known, and the railway bridge at the foot of Ludgate Hill and, in a less elaborate way, the neighbouring one across Queen Victoria Street are both impeccable on the score of inflexion of scale and material. As to the inflexion of level, their junction with

the neighbouring buildings is no better than that of the southern end of Vauxhall Bridge.

Only the briefest reference will here be possible to the manner in which the architectural *forms* of the bridge should be made to conform with those proper to the city. Sloping or battered walls, whether to bridge, abutment or embankment wall, will be eschewed as far as possible, for rectangularity is one of the characteristics of urban building, and indeed of all the nobler kinds of architecture. So well has this truth been realized in Japan that the framed construction peculiar to that country is not permitted the use of diagonal bracing, so natural and effective a device in this kind of building, when it is applied to ecclesiastical or other exalted ends. All such structures are composed of vertical and horizontal elements only. The highest type of urban bridge also will incorporate only horizontal, vertical and, of course, curvilinear forms. Its piers will discard the angularities of the older cutwater and its tall conoidal punctuation ; the rectangle and semicircle will gradually displace the triangle. Nor is the triangular form of the pointed arch any longer admissible. There is something final and self-sufficient about triangular forms which makes it impossible to apply to them to the full the blending and softening agencies of inflexion. They are the most selfish, they are the most disruptive among the whole architectural repertory.

The bridge will also look to its surroundings for the degree of articulation that it is needful for it to assume. In the finished urban picture this articulation, with its punctuating emphasis, is most often highly conspicuous, and so it will be in the bridge that intends to take its place in that picture. The piers will assume a dignity and formality that befits the occasion ; the arches will be outlined with a moulded architrave or with a row of voussoirs whose sequence and inter-

section with the horizontal stones will be studied with the most scrupulous care, while their soffits will, where the whole work is not heavily rusticated, be divided by parallel bands or hollowed out into coffers, as in the beautiful bridges of Gauthey. The parapet will be panelled or pierced, or will be set with rows of balusters, interrupted in suitable places by square blocks or projections crowning the piers, and at each end it will turn and flow gracefully into the embankment parapets. The design of the lesser parts will bear the authentic stamp of urbanity, avoiding the plain and untutored and the slight and mincing alike.

The precise nature of this urbanity may perhaps be most clearly deduced from two parallel examples of a bridge-builder seeking how to perfect the forms of a great urban masterpiece out of his previous experience. John Rennie's bridge at Kelso has been called a brilliant and original model for Waterloo Bridge. The twin columns on the piers, the idea of which Mylne had probably taken from Pertinchamp's contemporary bridge at Mozères and used in his Blackfriars Bridge, are there, and the flat roadway, the first of its kind to be built in England. But it is not difficult to see with what earnestness Rennie laboured to strike in his later work the grave and powerful note now expected of him. All is broadened and simplified ; the spirit of archaic Greece seems to have touched his pencil and given his Roman forms a more than Roman grandeur. Perronet, on the other hand, had, by the time he was called upon to design the Pont de la Concorde in Paris, produced a series of bridges, mostly urban or semi-urban, on a vastly larger scale than Rennie's Kelso, with the new construction which I have described as the continuous. The largest, the finest, the most daring of these was that at Neuilly, whose members were treated with the breadth and restraint proper to such an enterprise of unprecedented

structural economy. At first glance the Pont de la Concorde does not differ from it in any essential point of scale, but a closer observation will show how the piers are lightened with arched openings, how their faces are flanked with columns, and how everywhere a fuller and subtler life has been given to the whole organization of the design. I need only refer to the ample Tuscanesque bracket cornice of the later work, which takes the place of a great single semicircular moulding in the earlier.

Thus, while Rennie achieved urbanity by thickening his members, Perronet chose the way of refinement. The urban bridge is large in its features without being elephantine, vigorous but by no means brutalized. Its vigour, in short, bears the stamp of civilization, quick and attentive, and as deeply regardful of its surroundings as of the truths that reside within it.

§ 5

The importance of a proper urban inflexion in bridge design it would be hard to overstate. For while the difference between urban and rural street architecture is one of degree rather than of kind, the same difference in bridges is much more definite and more final. Why, it may be said, is not a bridge a part of the whole architectural scene, and does it not partake exactly of the urbanity or rusticity of that scene? We have only to examine the meaning of the epithet *urban* to realize that this is not so. The word is, indeed, applied to architecture in which a number of individual units are juxtaposed and together form a larger complex unit. Now this larger unit may be greater or smaller. Blandford High Street in Dorset is a lesser one, but it is distinctly urban, for its supremacy over the individual unit it clearly established.

London is a larger one, and who shall say that it is not more highly urban ? While for the outer parts of London, then, the urban formation of Blandford may be all that is necessary, its central thoroughfares require a more particular, a more exalted kind of urbanity, the kind that the eighteenth-century poet, Richard Savage, was invoking for the new Whitehall when he wrote :

> Far let it lead, by well-pleased Thames surveyed,
> The swelling arch and stately colonnade :
> Bid courts of justice senate-chambers join
> Till various all in one proud work combine !

It will be seen that in such a " proud work " as this the individual units have themselves assumed a corporate significance, with the result that their cumulative effect is of a much heightened urbanity. And though, as we have seen, this new social spirit is reflected in the bridges that come within its magic circle, yet these bridges have already derived a similar spirit of their own from the mere fact of their juxtaposition. For we must remember that in the country a bridge is invariably alone. The rusticity of the middle reaches of the Thames is of a sort that has been considerably tempered by urban influences, but you cannot see Richmond Bridge from Kew Bridge, nor Kingston Bridge from Richmond. All along this part of the river there is an average distance of three to five miles between bridges. While, therefore, the bridges have acquired an urban significance and consequently a formal urban inflexion from the concourse of dwellings along the bank (a concourse which the Thames may survey sometimes well-pleased but often not at all pleased), there has not yet occurred the concourse of *bridges* which is the home of the highest form of urban bridge.

We have approached the urban bridge from without, as it were, by commencing with the reflected or secondary

urbanity with which it is endowed by an assemblage not of bridges but of dwellings. There is, however, a profound qualitative difference between this secondary urbanity and that other native and intrinsic kind which should exist among the bridges of a great town. The first kind may be illustrated by imagining an Englishman upon a visit in Rome or Paris, each of which towns has a social code of its own, but one which, no matter how exquisitely organized, commands what is after all but a superficial observance from the Englishman. It is not *his* code, and though he conforms to it as best he may, it will always remain something a little extraneous if not definitely foreign. At his London club, however, he is among his own kind, and what in a Paris restaurant would be a scarcely noticeable error of deportment might well cause his expulsion here.

Among equals and compatriots the claims of civilized intercourse take on a new rigour. There are errors of inflexion between bridge and city that would become keenly aggravated if they occurred between bridge and bridge. The laws are similar, but here they are intrinsic ; nor does their intrinsicality arise from a correspondence between the *nature* of the units only, but from their *function* also. To the ordinary social code is superadded what I may perhaps liken to a professional code, which does not abrogate one letter of the first, but imposes an added scrupulousness in the relations with which it deals. And as among the workers in a great profession the rights of seniority are invariably observed with the nicest care, so we should require a new bridge to pay proper deference to an old one, and not disturb its beauty and serenity by playing leap-frog over itself, for example (by every token the favourite occupation of so many modern bridges), in its company. And this is all the more important because in the heart of a great city the building of bridges is

wont to go on multiplying within a limited area as the density of population and civic magnitude of that area increase. Between London Bridge and Westminster Bridge, the two earliest of our bridges, there are now half a dozen others that have been built from time to time, and these not serially as they occur along the river, but by a continued process of subdivision, the distances between them being uniformly and consistently reduced at the building of each. In Paris and most other capitals such a central area is delimited in the same manner. It is where new bridges interpose in this way between their hoary parents that their formal inflexion has to be studied with the utmost nicety.

I have suggested that the laws of inflexion here remain the same, and need, therefore, adduce only a single example to show with what strictness they must apply now that the opportunity to err and the consequences of such error are alike much magnified. The greatest arch of Old London Bridge had a span of twenty feet; Old Westminster as built by Labelye had a master-arch of seventy-five. Why was this arch not made wider? Among the designs proposed by eminent architects of the time are many showing arches varying between one hundred and one hundred and twenty feet. That a smaller arch was used is not due to considerations of structure. It was quite possible at the time to build arches of greater span than seventy-five feet, and I am inclined to the belief that John James, the architect of St. George's, Hanover Square, may have influenced the decision not a little, for he was an acute and a skilful controversialist. His own design shows a master-arch of eighty feet span, and that for the following reason. To build a bridge with great arches, he writes in an explanatory pamphlet, between two others neither of which have their largest openings so wide as the least of the new ones, would be "like making a great pair of gates to the inner room

of a house when the outer door is of a very mean size." The openings of Old London Bridge were indeed of a mean size, and John James and his contemporaries were faced with a difficult problem. They did not (they could not) know that the middle arches of London Bridge would be thrown into one not many years afterwards, and the whole bridge rebuilt well within a century upon an altogether new scale. They had to strike a just balance between the past, which was visible, and the future, which was only imaginable.

It must be said that in Old Westminster Bridge this balance was very adequately struck, and in the new Westminster, which is a metallic structure, the predominant scale of aperture has once more been reverted to after the interesting experiment at Southwark, individually one of the finest iron bridges ever built, but gravely at fault upon this point of intra-pontal inflexion. Its position between London and Old Blackfriars Bridges caused it to resemble, just as James had predicted, a great pair of gates separating two inner rooms of a house to which access may be gained only through much smaller doors. Its fault is, of course, less than it would have been before the rebuilding of London Bridge, for, as I have hinted, a new scale had then been set, and the master-arch of new London Bridge is twice as wide as that of Old Westminster.

We have now seen enough of this aspect of the inflexional law, which differs from the other only in the more immediate severity of its application, in its higher demands upon our critical exactitude and discernment. In the relations between bridge and bridge any infraction of it is punished with the worst appearance of heedlessness and vulgarity, and especially is this true in that central space where the generations meet, where the youngest takes its place not in sequence of time, but in the midst of the mighty dead. With them and by them it is that it will be judged. Surely upon such a meeting-

place of all the ages we must be careful not to let anything foolish or discordant intrude. No matter how broad our view, how exacting our standards, they cannot be broad and exacting enough when we are required to sign the page of our national architecture with an authentic work of our time, a work which shall stand for generations between, say, an architectural *Hero and Leander* and a *Lycidas*, and not, as it might seem more properly to belong, in a subsequent tome among its own compeers.

§ 6

Perhaps at this point it may have become more clearly evident why the turning of the chief beauty of the bridge away from its roadway should be of such vast importance in the creative development of the urban bridge. To begin with, one of the characteristics of civilization is that it always tends to include in its transformations all the material elements that come within its reach, and in a great city the river itself has become in a large measure urbanized. How else could so many of our finest bridges bear on their sides so much sculptural detail that can only be properly seen from a boat making straight for one of the arches? How else could that knotty problem of the placing of a statuary on a bridge have arisen? The problem, that is, whether a statue placed on the top of a pier should face inwards or outwards, should look towards the roadway or the waterway.

If the whole of the external aspect of the bridge had not become so definitely and completely absorbed in the inflexional totality of the city, there could have been no doubt in the matter. The statues would face the same way that Wren would no doubt have made those of St. John's College bridge face had he had an opportunity of placing them there. And whenever

a statue is introduced at this point it is, of course, the rule to make it look towards the roadway. Unfortunately, in doing this it at the same time turns its back upon the river ; and that is not all : the whole urban community and in especial the fellow bridges on each side are repudiated in that selfish gesture. I for one am content to find in this danger of grave inflexional error (of civic barrenness, if you will), this impossibility of full and proper adjustment, the reason for the paucity of statues placed on a bridge parapet. No longer will it be considered anomalous that a bridge should disclose itself to those only who do not use it. In doing this it is making a wise discrimination between use and beauty, between the functional and the æsthetic. For those who use a bridge are content to walk over it in the shortest time ; they desire nothing less than to be hindered on their way. Round about, however, there lies the city, and it is to this that the message of the bridge is addressed. It is well that its utmost artistry should be turned in this direction ; and in a highly developed urban picture the reverse would indeed be an unbearable affront. And as for our own Vauxhall Bridge, it is the town and river rather than the bridge that are to be blamed for the fact that Mr. Alfred Drury's statues are about as visible as though they had been concealed in the hydraulic engine-rooms within the piers of Tower Bridge. When our Grosvenor Road has learnt the lesson of complete urban inflexion they will no longer be invisible, and when the Thames has been restored to its position as a great and splendid waterway they will give pleasure to thousands who now ignore their very existence.

The most famous examples of statues turned inwards towards the roadway of a bridge are to be seen at Prague and Würzburg. In both the statues are seventeenth-century additions. But the bridges to which they have been added

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are nodal rather than urban ; they antedate the towns of which they are a conspicuous but not profoundly inflected embellishment. There is nothing in the bridge itself of that opening-out, that *unclosing* (if I may be pardoned the Gallicism) towards a magnetic something without, a new focus, a new orientation, that can best be likened to a flower stretching itself towards the sun. And though when the statues were put up (at Würzburg they have independent pedestals set in the recesses over the piers) the city round about had grown to another magnitude than it could boast in the bridge-builder's time, there is something entirely consistent in their falling in with the prevalent mood of the bridge. Like it they are more interested in the people that pass across than in the urban scene that these same people have afterwards erected around it. And such partiality is due to the immature state of the town in the days when the bridge was built rather than in the superiority of the people crossing.

Does this superiority never count? Is it impossible for the balance to tip on the side of the human user because he himself exhibits some peculiar greatness, real or imaginary? Indeed, was not this the very thing that prompted Wren to advise " a handsome balustrade, upon the piers of which, for ornament to the walks, you may set urns, pyramids or statues "? For whom were these urns and statues intended, if not for the masters and Fellows of St. John's College? And is it upon a great urban waterway surrounded with buildings and terraces that these statues will turn their backs? No, it is only the rural Cam and the bargemen that ply upon it that have to put up with this chill behaviour, and what are they to the dons who have made the Cam and its lawns illustrious? There are one or two similar bridges in Berlin, each crossing a waterway of very little account; one of them, at any rate—Schinkel's Schlossbrücke—is also designed to honour travellers of more

than ordinary eminence. Thus we see that there are bridges in which it is legitimate to turn their comeliness towards the people who use it. Not, we must add, to please them, but to exalt.

It should be noted, however, that even where the human being has no claim to be exalted he is yet invariably entitled to the respect of the thing he has made. It is only occasionally that the bridge is thus required to make him magnificent; it is everywhere and at all times of the utmost importance that it should not make him abject. In the presence of his handiwork he should always be the greater of the two, no matter how great the other may be. There is no place for the Juggernaut in the arts of a civilized nation; we do not want the fruit of our labour thus to turn against us and rend us. It is upon this score that the great metallic bridge with an overhead arch, the bridge of the Austerlitz type, already found wanting in other respects, stands doubly and trebly condemned. Within such bridges as those at Dirschau, in Germany, the human being moves as a prisoner in a gigantic cage of steel. You do not walk over them, you plunge into them. Crossing such a bridge a man might be a helpless animal about to be crushed in the jaws of some vast machine, a "wee, sleekit, cow'rin, tim'rous beastie," fleeing from the share of a supernatural and gauntly articulated plough. Place a man on the summit of Mont Blanc, and he is lifted out of himself, he appears greater than before; send him struggling up Mount Everest, and his stature partakes of the heroic. Leave him at the foot of a great viaduct such as that at Segovia, or the still more famous one in the Gard Valley, and something of the majesty of his handiwork is reflected upon him. Stand him on the uppermost tier, and you would say that the broad-limbed structure lay outstretched at his feet to do his bidding. But what becomes of him within the intertwined metal bars

and plates of the bridges of Dirschau and Bommel, and Cologne and Passau, and Saltash and Mainz, and all the others of their kind ? Shall we think any the better of them because of the gateways and pylons of stone, and the pinnacles and equestrian statues, wherewith they greet the traveller about to venture into their barren wilderness of steel ? Will he be thinking of the bravery of William IV as he walks through the resounding tunnels of Cologne ? will he be comforted by the mediæval gateways that guard the entrance of a dozen similar masterpieces of engineering ?

Surely if a man must be thus immured in a cage of iron it is better put under the bed of the river as at Stepney than suspended in mid-air. This reckless display of an ignominy, the need for which I will not here dispute, savours of ignorance and brutality. But I am inclined to think that the metal *through bridge* is diverted from its proper function when it is thus used for unprotected human beings. It has another and more legitimate use, in whose effect upon human dignity we shall find little to cavil at. London is indeed to be congratulated in that of all the bridges of this type that cross the River Thames, there is not one that does not harbour a creature of its own kind, a product, like itself, of the boilermaker's skill, whose strength and swiftness are nothing daunted by the beetling lattices through which it speeds. Within such a bridge the railway engine is as perfectly at ease as a bullet flying through the barrel of a gun. Moreover, where a footway for human beings is included in these Thames bridges it is usually —as at Charing Cross—applied to the outside of the girders as though it were an afterthought. As an afterthought it is defensible ; as a path following the *outside* of the prison wall it need not put the human body quite out of countenance. More than one glowing page has been written on the prospect of London from the Charing Cross footbridge ; is it imaginable

that they could have been inspired by the view from *within* the great steel corridor and its bars ? And why not ? Because the view would have been impeded ? A view is never made less thrilling for being that ; on the contrary, it may, as Baudelaire has pointed out, gain in depth, richness, poignancy, the more narrowly it is hemmed in. It is not because the presence of the bars restrains the eye, it is because it restrains the body and the soul that London, or any other city, cannot be seen from within a metal *through bridge* with that opening-up of the sensibilities which is necessary for the experiencing of beauty. Release the man and let him stand outside in freedom, and though to an outsider his physical insignificance may still be apparent, he himself will be much less acutely aware of that spiritual insignificance which before oppressed him.

Let it not be feared that in examining the effect of a bridge on the soul of man we are trespassing upon the irrational domain of the subjective. We are not asking the man what he thinks of the bridge. We are pursuing the law of inflexion, not to the fringe of its rightful sphere of influence, but to its very centre. What there is at the centre of that greater world whose bewildered inhabitants we are it is only possible for us to describe in music and in myth ; of its nature we know nothing save what we may observe of influence, dark or bright, in the works by which we are surrounded. But at the centre of our own human world is that which it behoves us before all else to know clearly, for our knowledge of it is the measure of our greatness. And since the works of man issue from the spirit that is within him, woe to that which casts a gloom upon that spirit, or causes it to fall into dishonour, if but for one moment ! No greater sin than this is known to the laws of visual form by which our buildings and bridges must each one be judged.

CHAPTER IX

§ 1

SOME of the practical questions which to-day confront us when we turn our attention to the bridges of England may not improperly be touched upon in these concluding pages. It is too often ignored or forgotten that England is a country of bridges, and has been so since Elizabethan times, when the chief pride of our country was aptly summed up in the famous doggerel :

> Anglia : 1, Mons ; 2, Pons ; 3, Fons ;
> 4, Ecclesia ; 5, Femina ; 6, Lana,

which, it will be observed, gives bridges second place. There were about nine hundred of them by the middle of the seventeenth century. Are these nine hundred still with us ? Alas, their numbers must by now be very sensibly reduced, and that not because of any inherent defects, but because we of the twentieth century insist that our roads and bridges shall carry burdens which eighty years ago would only have

been entrusted to a specially constructed track of steel. As the volume of modern traffic swells, one bridge after another becomes inadequate both in size and strength ; too narrow, that is, to contain it, and too weak to support it. What is to be done ? Shall it be widened, or strengthened, or both, or neither ? Such, in brief, is the choice open to those whose duty it is to provide smooth and ample roads and bridges for the thousands of internal combustion vehicles that daily troop forth from American and European factories. It is not an enviable task ; to some it may seem a never-ending one, comparable to that upon which poor Sisyphus was (and perhaps is still) engaged. What width must the widening add, what strength the strengthening ? Is it enough if they serve the need of to-day, or must they be prepared for that of to-morrow, and perchance the day after too ? Roads and bridges that once were wide are already thought narrow, and will be narrower still in a few years' time.

The increase of our traffic bids fair to continue rather than to abate. There are two facts, however, which will, I think, combine to make the question of our old bridges less pressing than it is at the moment—except, of course, that of our urban bridges, to whose special problems we must return in another section. There is the modern tendency, not very strong as yet, but clearly to be seen, towards a revival of water transport, and there is the construction of new arterial roads and by-passes for fast vehicular traffic, most of which will have bridges of their own. The attention that is once more being paid to our rivers and canals as means of communication is a happy sign that must rejoice all who care for the beauty and dignity of bridges, for a beautiful bridge standing in a foul and neglected stream is a saddening spectacle of degradation and decrepitude, and as for new structures, who would throw away his finest inspiration on a sewer ? But it is no less to be

welcomed in that it will put an effective check on the expense to which we are put in keeping our highways and bridges forever smooth and safe. Almost imperceptibly, large works are being established by the side of our long-disused canals. The movement is clearly there, though still at a very difficult stage of its progress. The work of the Royal Commission of 1906 was not profited by, and is now quite forgotten. The Committee set up shortly after the War presented a second interim Report three and a half years ago. Nothing more appears to be following for the present. But the enlargement of the hundred-mile waterway between Hull and Nottingham is proceeding apace, while the Corporation of Birmingham is busy considering the reformation of the system of canals by which that city is surrounded.

Some time ago a Liberal Member of Parliament put forward a suggestion that the Regent's Canal should be dried up and turned into a fast motor road. The suggestion comes half a century too late. Some of our railways were actually laid on the bed of old canals, but we do not now live in the age of rapid and enthusiastic railway expansion. We are beginning to realize the vast economic burden that the upkeep of our great motor roads imposes upon us, and when the users of these roads are made to bear a reasonable proportion of this burden, to which they now contribute only a small amount, they too will begin to realize the attractions and advantages of water transport. A scheme has also been propounded for covering in the River Thames itself. Now the Thames may be foul enough, but it is not so foul that we need to bury it from the sight and smell of decent men. It may have fallen a long way since Spenser wrote his *Prothalamion* and Drayton addressed it in a sonnet, but let us be careful before we drive away from London the stream to which London owes its existence. Fortunately there is a perceptible movement in

AQUEDUCT, VALENS, CONSTANTINOPLE

the opposite direction, and as our waterways rise in our esteem once more the bridges that span them will come into their own also. But perhaps in the matter of the conservation of old bridges the building of great modern roads will have an even wider result. It is not, I believe, generally realized that during a period of six weeks last year road schemes to the value of over one million pounds were sanctioned in various parts of the Kingdom. Under the auspices of the Ministry of Transport, road after road is being undertaken which will divert the main currents of traffic away from the older roads and bridges.

But if the problem of the older bridges will be less acute when in ten or fifteen years' time they are left to carry only the local and more leisurely tributaries of the main streams of traffic, it does not follow that we can afford to relax our vigilance to-day by one jot. It is not to-morrow that they will be threatened, it is *now*, and it behoves us to formulate a policy that will enable us to deal with individual cases quickly and effectually as they arise. The famous Clopton Bridge at Stratford-upon-Avon has recently been the subject of warm and prolonged controversy. The Stratford Preservation Society made up its mind that the bridge must not be disturbed, and that a new bridge should be constructed a short distance upstream and the road (it is the main road between London and Birmingham) diverted thither. In this attitude they have received the full support of the Society for the Protection of Ancient Buildings, and have commissioned a well-known engineer to prepare a report on the subject. It is not necessary that we should in these pages take sides on a hotly debated issue, but one or two facts may be pointed out that are often lost sight of.

It has been said again and again in the public Press that Clopton Bridge has already twice been widened and that a

third widening will make only a very small difference to its appearance. Such a statement is definitely, if not purposely, misleading. The bridge has only been widened once, and that only by four feet. The so-called second widening consists of an iron footpath which was applied to the upstream façade of the bridge a century ago. A projecting footpath may be bad enough, but it is not a widening of the *bridge*. And how is it possible to liken the existing addition of four feet of masonry to the proposed addition of twenty-four feet? The comparison is ridiculous. A bridge originally sixteen feet wide may be tolerable when increased to twenty, but who will assert that it will look the same when it is widened to forty feet? But, it has been urged, the very stones will be replaced that Sir Hugh Clopton used! Municipalities have little sense of humour. Let us not try to shut our eyes to the impossibility of reconciling the old with the new in such an example as this.

Here and elsewhere we must face the choice before us fully and bravely: it is a choice between *destruction* or *preservation*. If we are for destruction we must not shrink from saying so; to replace an old structure with a fresh one is a perfectly legitimate act, and one that need not be tricked out with inane arguments and made to look like its exact opposite. But we must have a reason of some substance before we decide upon it. And the best reason for reconstructing a bridge like that at Stratford to two and a half times its original width would lie in the certainty that if a new bridge were built in the immediate neighbourhood, the old one would fall into complete desuetude. A living bridge is always preferable to a dead one, just as a human being would willingly submit to an operation that would change his entire physical appearance if his life were to be saved thereby. But the obliteration of a visible individuality, especially if it be at the same time

intrinsically beautiful and historically endearing, is a sacrifice that comes next only to death itself, and one that we should not call upon a bridge to make unless the alternative is put as completely beyond doubt as is humanly possible. Now the life of old Clopton Bridge is a peculiarly active one. Not only is it a vital link in the main road from London to Birmingham, but three other roads scheduled under Class I by the Ministry of Transport also converge upon it. The possible fall from such a full usefulness to complete superannuation would therefore be a very considerable one here. Suppose a new bridge is made to take the main road traffic, will there be a reasonable and satisfying function left for the old bridge to fulfil? Would it be in a position to justify its separate survival? This is the sort of question that must be answered fairly and completely if a proper solution to the problem of preservation is to be found.

But the case of Clopton Bridge is not only typical of many, it is also of interest in that it has led to the inception of an organized movement which will, let us hope, make the wanton destruction of fine bridges difficult, if not impossible. When the Society for the Protection of Ancient Buildings, in conjunction with the Stratford Preservation Society, approached the Minister of Transport in order to try and save old Clopton Bridge, it was pointed out to them that if the Ministry possessed a schedule of all structures worth preserving, it would be possible to give thought to this important question at the beginning of negotiations instead of at the end. The public as a rule does not hear of the great road-making schemes until they have passed the crucial stages in their progress through Government departments, and at such a time the path of the objector is rendered infinitely more difficult. A list of this sort is, therefore, being made up at once. The Minister of Transport is to be congratulated upon the courage with which he asked a private

society to do for him at once, and for living structures, what a Government department was already doing in its own imperturbable fashion for ruined ones. His act contained no reflection upon the Ancient Monuments Board of the Office of Works, which is following a laborious programme laid down by statute with substantial and painstaking care. As for the Royal Commission on Historical Monuments, it is not expected to finish its work for generations; moreover, its survey comes to an abrupt close with the year 1714, that is to say immediately before the golden age of English bridge-building. The Society for the Protection of Ancient Buildings has wisely put back this limit until 1800, but enterprising though this decision may be, it seems a pity that they did not add yet another quarter of a century, during which many exquisite bridges were put up in England, including one that is said by some to be the finest bridge in the world. The reason is that the Society (as its name shows) is, like the Board and the Commission, concerned with old things rather than with beautiful things.

This attitude is a very general one. I have before me the report of a Committee of a County Council in Wales at which the Society's request for information was brought up. The very first remark that was made by a member was that there were no bridges of historical interest in the county. The intrinsic qualities of anything left to us by another generation are often, as we have seen elsewhere, extraordinarily hard to disentangle from the adscititious charms of history. But unless this is done the cause of preservation will never be properly understood, nor will it meet with the success it deserves. The effect of such a concentration upon the mere antiquity of a thing is a denial of all that civilization stands for. Shakespeare is not great because his plays are three hundred years old; if we distinguish him above Jonson and Massinger

it is because he was different from Jonson and Massinger, and indubitably greater than they. A work of art is not like a sum of money whose magnitude is proportionate to the time that has elapsed since it was first invested in Government bonds.

The very first step, therefore, in any scheme of preservation, is to make up our minds *why* we desire to preserve the threatened object. The next step is to seek how we may save this object—whether it be a bridge or anything else in the world—without rendering it useless, shameful or ridiculous. There are things which are meant only to be looked at, and such things make very fine museum pieces indeed. It is quite otherwise with bridges. Thirdly, having established the bridge's claim to salvation, and found a decent way of granting such, we must not be deluded into believing that the individuality of the old bridge will survive a really extensive tinkering. There is great danger that having decided wisely on the first two points, we may yet, after spending much thought and money on the task, find ourselves with a bridge on our hands that is neither old nor new, possessing no identity whatsoever, an ignominious blend of things and qualities that cannot be reconciled. It is here that the great truth to which I have referred must be scrupulously borne in mind: between destruction and preservation there is no golden mean.

§ 2

With the rural bridge the choice is always more or less clear. You may place your wide new bridge where the old narrow one stood, or you may leave the old bridge intact and build the other some distance away from it. In towns there are no such alternatives. The old bridge holds the only possible position ;

you cannot leave the bridge and go elsewhere. You must either leave it or rebuild it, and that in the one possible place; and if you leave it you must abandon your plan for a wide crossing and unimpeded traffic.

Let us describe the difference by means of an analogy from human life. The urban bridge may be compared to a man who holds a position of great power and responsibility in the affairs of a large concern. Suddenly these affairs expand beyond all that has hitherto been thought likely. The director is long past middle-age; his strength has its limits that he dare not overstep; perhaps any such exertion brings its immediate punishment of weakness and ill-health. Two things only are possible. Either he may retire from office and spend the remainder of his days in some rural retreat, or he may continue at his work, striking as best he may an exasperating balance between illness and inadequacy, between failure in work and failure in health. The rural bridge, on the other hand, may be likened to a man in a position of much less eminence and correspondingly less inflexibility. To him there is yet a third alternative. Not having risen to a point at which he stands above the majority of his fellows, he is still able to regulate his task according to his strength by an adjustment with theirs. His is a much more leisurely appointment, and it is not difficult for him to delegate a sudden multiplication of work to younger and abler men. If this is done, not only will the work go on with all dispatch as before, but his own strength need by no means be taxed to the point of danger. The solution is, provided it can be properly effected, a happy one. It is one that the urban bridge may not attempt. The work of the urban bridge cannot be delegated; it must be performed there and then, and if the old bridge cannot satisfactorily perform it a new one must take its place.

The necessity for this decision cannot, it is clear, be evaded.

If an urban bridge is too narrow or too weak, it must be widened, it must be strengthened : it must become what is in effect another bridge. But there are degrees of widening and of effacement of personality, and our task in a case of this kind is to estimate what amount of work can reasonably be required of a bridge, and consequently what amount of widening will be necessary. Exceed the necessary, and we shall be guilty, if the bridge is a fine one, of a piece of gratuitous vandalism. Not only would this be so because the bridge had become a *different* bridge, but because, if the old bridge is adequately designed, the width of its arches will bear a definite inflexional relation to their span, their height, the peculiarities of the waterway, the rise and fall of the tide, and all the other elements, within the structure and without, that determine its formal organization. If this proper inflexional relation is lacking, the bridge will not be beautiful and had as well be taken to pieces and dumped into the sea. If, on the other hand, the bridge originally possessed this quality, we shall deprive it of its whole æsthetic significance when we disturb or curtail it in any material way. The effacement of personality should not, therefore, be confused with the effacement of identity : it is an infinitely more serious thing than that.

Is it possible, then, to widen a bridge without destroying its formal consistency ? Experiment alone can tell, and to this effect we should take pains to find out, by means of models and perspective views, precisely what the effect of a widening would be. It may, of course, confidently be assumed that as the width of an arch is usually seen only in considerable foreshortening, a given quantity added to it will be less noticeable than the same quantity added upon the longitudinal plane of which we have a full frontal view. On the other hand, it should be realized that every inch added to the width of the arch increases the depth of gloom within it. The arches of a

bridge are not culverts or tunnels ; the eye should be able to look *through* them instead of merely straying *into* them ; they should not arrest it with darkness, but liberate it in light.

What we have to decide, then, is the minimum labour that we must exact of a bridge without lessening its importance or abrogating its dignity. Should it be made to carry three lines of traffic, or four, or six, or eight ? Need its width be the same as that of the street or road abutting upon it ? Æsthetically, it need not. Practically, it may be equally unnecessary. The street must have space for stationary vehicles, a bridge needs none. Where a trajectory is unimpeded, its width is of less account ; a long railway train would not arrive any faster at its destination if its coaches travelled side by side instead of behind one another. It is the stopping-places and level-crossings that cause congestion.

Still, it should not be forgotten that in a concourse of vehicles it is the slowest that sets the pace. The advocates of latitude in roadmaking derive perhaps their chief support from the necessity of freeing oneself from this restraint, of overtaking, as it is called, on the road, thus rendering the power of the slowest nugatory. Granted the importance of this overtaking, it must surely be agreed that two lines of traffic each way is all that we can reasonably impose if the admission of more will entail a notable artistic loss. Or are there to be unnumbered hierarchies of speed, is there to be room for all degrees, and varieties, and shades, and must the vehicle travelling at thirty-five miles an hour be put in a position to overtake one travelling thirty-four, and so on throughout the whole range of mileage ? Surely across the few dozen yards occupied by a beautiful bridge we may well ask our motorists and horse-drivers to exercise a little of that self-restraint and mutual adaptability which pedestrians are so frequently called upon to show. It will not be impossible

THE BRIDGE OF MILLS, MEAUX

for them to divide themselves, with or without legal guidance, but preferably without, into two groups, the slow and the fast. If they can be prevailed upon to do this the traffic problem on our bridges will have gone a considerable way towards its solution, provided, of course, that the approaches on each side do not constitute an impediment of which the bridge has to suffer the consequences. Most of our bridges, indeed, are blamed for sins that are really committed by the approach roads ; the eastern approach of Westminster Bridge is a notorious case in point.

We noted that the urban bridge could not, like the rural, be rid of the major portion of the new burdens imposed upon it by the present century. I say the present century, but I believe that if someone were to calculate the average weight of vehicles in 1914 and of those of 1924, we should be not a little startled by the difference between them. Some of our bridges exhibit notices restricting the weight of vehicles that pass over them. Many of these restrictions cannot be more than a dozen years old, and were obviously intended to be observed when they were first laid down, and yet almost every other vehicle that rides by must surely exceed some of them by at least one half ! The urban bridge cannot hope to be relieved of this great modern increase of weight, but that it can be succoured to some extent may be gathered by recalling the process of subdivision by which we saw them multiply within the central area of a great city. This process may still go on ; indeed, it is of the utmost importance that it should go on. It is the clear duty of every expanding town to continue building such bridges. During the three-quarters of a century that preceded the building of Rennie's Southwark Bridge in 1819, the Central Thames between London Bridge and the Houses of Parliament was provided with three new road bridges in addition to Southwark itself. During the whole of the

century that has since elapsed not one has been added. And of which of these periods will it be said that it has witnessed the greatest increase of traffic of all kinds ?

In most of our towns we have similar arrears of bridge-building to make up. It is unimaginable that we should really cease to build bridges just at the moment when we most need them. Were we to do so, the future of the movement for the preservation of older bridges would be dark indeed. There are laws to punish and prevent the sweating of human labour and the cruel treatment of animals, but there are no laws to prevent the sweating of bridges. We ride them to death, and when they show signs of failure we fly into a temper, and tell them that they were never really of much use, that they were ill built and that their prettiness was always overrated. It would be better if we were to treat them as a good master treats his servants, employing always a sufficient number to do the necessary work smoothly and regularly and without inflicting injury upon themselves. If his household increases, so does his staff ; in this way nothing will be neglected that should be done, no one will be left unattended who requires assistance, and as for the servants themselves, they will live longer, and work more cheerfully, and who shall say that they will not love their master better ?

But perhaps at certain hours and in certain seasons there may be less work crying to be done ; there may, who knows ? be intervals of leisure and even idleness. Well, the good master will not grudge them those moments, and we also may well be content to see our bridges standing idle sometimes when the household sleeps or disports itself away from the house. For if these pages have proved anything at all, it is that of all the works of man there is none that has such heavy burdens to bear as the bridge, nor is there any that finds such pleasure—a pleasure bordering on fulfilment—in idleness, or

becomes invested with such a beauty, but a beauty wholly disinterested, like that of Kant's ideal, and disclosed only to him who looks towards the bridge idly, not purposing to mingle with the crowds that press backwards and forwards crying, What shall we eat ? and, What shall we drink ? and, Wherewithal shall we be clothed ? We do not want our bridges to be beautiful only any more than we want our men and women to be beautiful only ; both must be useful as well if they are to live happy and dignified lives ; but who is there that would not turn from the sight of a beautiful woman bent and broken by excess of labour, her strength worn away by tasks to which it was not proportioned ? Let us demand of our bridges that they shall do their full share of work, but let us be careful to demand no more. And if sometimes they are required to do a little less than they are capable of doing, let us take it for what it is, a compliment to our liberality, our humanity, our susceptibility to fine things ; a sign of our freedom to make Beauty our own, and her sojourn among us a grateful one.

§ 3

In the foregoing pages we have concerned ourselves, as the title of the book predicted, not so much with bridges as with *the bridge*. What is the difference ? An essay on *bridges* would very naturally begin by enumerating the species in the hope of extracting from such a list a more or less vivid picture of the genus. But an essay setting out to deal, like the present, with *the bridge*, must make straight for the genus and leave the species to take care of themselves. This it is that we have done, and one of the advantages of our position has been that it has allowed us constantly to keep in view that higher genus of architecture, of which bridge-building is but one of the

constituent subaltern genera. Had we adopted the specific method, we must of necessity have lost sight more than once of this subservience of our subject to another which I have thought it just to acknowledge in my sub-title. For the bridge is only one of man's many works of architecture, although I have attempted to show that it is not the least fascinating. Its historical significance I have touched upon only in order to establish a distinction which has been of considerable assistance in our study of the æsthetics of bridge-building. That is to say that, while it has been necessary to trace the effect of the nodal bridge in human history, it has not been possible to trace the effect of the bridge in general. To do this would have involved a greater admixture of history than our generic treatment would allow. Of the part played by the bridge in the evolution of religious communities, in the downfall of the feudal system and in the establishment of central monarchic authority, something may, I hope, be written elsewhere: this certainly is not the place.

A bridge may *be* many things. If you will open Murray's *New English Dictionary* you will find a long list of the various kinds of bridges, and Larousse has a longer one still. Whatever it may *be*, however, it can only *do* one thing. It carries one way across another; it can do nothing else. These ways may *be* of different species, and the species of the bridge will vary with them. If I devote a few of the remaining pages to a consideration of some of these, it is not so much in order to introduce the reader to the familiar themes of the past as to direct his attention to some of those developments that are possible if not inevitable in the near future.

In the preceding chapters we cast a brief glance at the rise of a new factor in bridge-building, the factor of level. The result of this innovation was twofold. First, it caused the ordinary kind of bridge, the kind that linked up stretches

of road separated by a physical obstacle, to flatten itself out. It grew increasingly important that an artificial hillock should not be suddenly introduced in the trajectory of the road. But the other result is more notable, for it furnished a new and practically inexhaustible motive for the building of bridges. Formerly a bridge had been built to take the road *across* an obstacle that could not otherwise be overcome. At the rise into prominence of the factor of level, a bridge was built to take the road *over* something that was not in itself an obstacle at all, but merely an actual or a potential inconvenience. It is thus that we get the viaduct and aqueduct, both of which are cast across a valley merely in order to maintain a uniformity of level; whether the one carries a road or a railway, or the second a conduit or a canal, does not materially affect the question. Their purpose differs from that of the earlier bridge in that the maintaining of a fixed level is not a necessity of permanent communication, it is an aid to easy and rapid communication. Their design differs (as we have seen) in that the lower way is not to be compared with the upper, which is as straight, direct and concentrated as the lower (if this can indeed be called a way), is extended and diffuse, and consequently cannot claim the same inflexional courtesy that is always shown to a navigable river confined within definite bounds. The viaduct and aqueduct, in other words, are typical products of the immediate past, whose chief task was the perfecting of our methods of communication to the farthest possible limit.

Now observe what happens to-day. In the improvement of our means of communication by land, very little remains to be done. The locomotive and automobile, the iron railway and the roadway of smooth asphalted concrete, can perhaps be improved upon for cheapness, wearing power and rapidity of construction, but the power of quick and easy transit which

they confer upon the modern wheeled vehicle has, it may be said, reached its perfection. Our present concern is indeed to make more and bigger roads, but not smoother and more perfectly levelled roads, for these we already have. In especial we are concerned to produce more and more vehicles. Now just to the extent that we increase the number of these vehicles do we cause their aggregate movement to become more and more of a continuous stream. The line of vehicles on rail or road has to be *crossed* just as the waterway was crossed by the early bridge. You could wade or paddle yourself across the stream, but at considerable risk and with much delay. To-day the crossing of a stream of vehicles by another stream or by a body of pedestrians is attended with the same risk and sometimes with an even greater delay.

It is necessary that we should clearly recognize the importance of the change that has here taken place. During the nineteenth century the attention of bridge-builders was momentarily distracted from the crossing of obstacles, that it might concentrate itself upon that other and much more leisurely task of equalizing the levels of a given trajectory. I do not say that the mere crossing of definite obstacles ceased, but it certainly assumed a secondary importance except at the two extremes of the scale of magnitude. In the very largest as in the smallest of bridges it was still the most conspicuous end; the great bulk of bridge-building, however, ignored it. Neither should we to-day have to devote much thought to this original function of the bridge were it not for the new obstacle of continuous vehicular traffic that we ourselves have created.

The consequence is that in all up-to-date railway construction the level-crossing is unknown. In England, where railway development is stimulated by private ownership, it was never popular. With our road traffic less advance has

been made thus far, but the necessity of providing a safe and expeditious means whereby a stream of vehicles may be crossed by vehicles and pedestrians alike cannot possibly be escaped. It is a question which will have to be solved somehow during the next ten or twenty years. In London and in many another great town, the level street crossing is already infinitely more dangerous and difficult than the level railway crossing. What form the solution will take it is not possible to say, but the elevated crossing must come, in one form or another, though not, it is to be hoped, in that foreshadowed by Sir Alfred Yarrow's recent model, where a platform was shown put up in the middle of Oxford Circus, with no regard whatsoever for the architectural configuration of the place. The effect of such a structure as that would be much the same as that of a stepladder left behind in the drawing-room by a forgetful housemaid.

If I have succeeded in proving anything at all in the last chapter, I trust it has been made clear that an important elevated crossing for vehicular traffic should be *designed* as the Holborn Viaduct or rather as Waterloo Bridge is designed, with a full realization of all that is implied by its juxtaposition with streets and buildings. From this necessity we may deduct one axiomatic rule. The elevated crossing must occur at a higher level, hence the neighbouring buildings must take cognizance of this level; that is to say that the main floors of these buildings must be placed at or near this upper level, and in any case not below it. For it is an obvious but inflexible law in architecture that though a principal floor in a building may occur *above* the level of the entrance from the street, it cannot occur lower down. And if you enter a building from two different levels, the upper will always dominate the lower, upon which you can only place apartments of subsidiary importance. It is æsthetically impossible, therefore, to

suspend an elevated way in the middle of Oxford Street while the shop windows remain at the level of the pavement. We must, it will be agreed, make up our minds to create new elevated ways for these high-level crossings, in such a manner that the lower floors of the buildings abutting on this way will be made neither useless nor ridiculous by its presence. We have such viaducts already, and we shall doubtless have more before long. Where and by what means they are to be erected it is not germane to our present purpose to discuss. I have done enough if I have indicated how their design must be influenced by the formal laws which have been expounded in the previous chapter.

These laws apply somewhat differently to the smaller type of bridge which we shall sooner or later see erected for the use of pedestrians. Such footbridges will very naturally be constructed of iron or steel, and their forms will be akin to those of the metal trimmings with which our buildings are adorned. If they are designed with a proper regard for architectural logicality they will no more compete with the surrounding buildings than do the balconies that protrude from these, or the electric lamp-standards that are put up in front of them. If they are not so designed we may indeed expect the worst. The modern fire-escape has shown us to what depths of vulgarity this sort of structure may descend. We may take it that an elevated footway will be all the better for being attached to the buildings on each side and adequately composed with them, and perhaps the ideal type would be one in which the stairs leading to it were contrived within the building itself, and separated from the street by a gateway. We should then have a bridge for which there are innumerable fine examples, and in the designing of which the opportunities of grave inflexional malpractice would be materially lessened.

It may be argued that the alternative of subway crossings

BRIDGE AT BASSANO OVER THE BRENTA,
SUPPOSED TO BE DESIGNED BY PALLADIO.

present a much less complex æsthetic problem, though it is well known that the proper treatment of the stairway openings is difficult enough. But we saw at the end of the last chapter that where an enclosed cage or tunnel is necessary, it is better to put the machine into the tunnel and leave the human being the freedom of open space. I forget whether it was Ruskin or Morris who said that if you cannot do without railway trains you can do nothing better than run them through an underground tube. May we not affirm that the reverse of this statement is truer and more important, and say that if we cannot do without subways we should use them for our mechanical vehicles and not for unprotected men ? But it is unnecessary to stress this point, for people have come to their own decision long ago, as may be seen at the Bank, at the junction of Whitehall and Parliament Street, and at the many other places where costly subways would be completely deserted did they not at the same time give access to railway stations and public conveniences.

§ 4

Our bridges to-day are built either by private or by public bodies. Those built by public bodies are bound to grow more numerous in comparison with the others, for the golden age of railway development, which has been so prolific of bridges, is past, and the highway once more occupies the centre of the stage. These highway bridges are under the jurisdiction of local government authorities, and it is to these that we look for the building of our new bridges and for the active preservation of the old. We can do no more than urge upon these authorities the course that we think most proper and most likely to give us the best results. With old bridges this is

largely a matter of policy. Preservation is a negative accomplishment rather than a positive; once a right principle is established and its reasonable observance guaranteed, the result may be left to take care of itself. The designing of new bridges requires something more: it requires creative ability of the first order. Is our present system of local government so constituted that it contains within itself this ability? And if it does not command it within its own ranks, does it make a practice of recruiting it from without, and that with a proper regard for its adequacy?

Let us take one question at a time. What are the functions of local government? We may enumerate several: the administration of the poor-law, the education of youth, the interment of the dead, the dispensation of justice, the maintenance of highways, the removal of sewage, the enforcing of a scheme of building and working and living that will allow the community to enjoy a proper measure of health. These latter three are generally entrusted to the surveyor. A local government surveyor, then, is a man who understands the upkeep of highways, roads, bridges and public paths; who is able to build sewers and maintain them in working order, sufficiently cleansed and ventilated; who knows, where necessary, how to disinfect the sewage, to put in a water supply, to keep a vigilant eye on river pollution, on noxious trades, on infectious diseases and a hundred other things. Moreover, he is personally answerable for the proper drainage of every house within his area.

Surely, if any profession calls for an encyclopædic knowledge and a keen and active mind (not to speak of the olfactory sense), it is that of a local government surveyor! His task is an enormous one, and its proper fulfilment cannot be an easy thing. So vast is it that the supervision of highways is nowadays not infrequently entrusted to a separate official,

the engineer, leaving the surveyor to rule his sanitary kingdom with an undivided mind, and occasionally with a sanitary inspector to assist him. But though he is often thus relieved of a part of his duties, it is to be feared that he is just as often burdened with fresh ones. Many a district surveyor is expected to be not only a sanitary expert but an architect as well, and is ordered to prepare the designs for schools and workhouses and other buildings required by his authority. Incredible though it may appear, there are surveyors of this kind who are also tolerably skilful architects, but surely this is a little too much to expect from one man. Whether the highway department is entrusted to the care of the sanitary authority or to a separate engineer, it will be seen that the one is as ill-equipped as the other to design new buildings or bridges. Fortunately, many of the larger authorities have realized the advantages to be derived from the appointment of a third official—this time an architect and nothing else—and to him they entrust the design of their buildings, and sometimes of their bridges also.

The answer to the first question is now moderately clear. Only the very largest local government bodies contain within themselves the architectural skill that alone enables men to design satisfactory works of architecture, and among these by no means all choose to include their bridges among the work they give their architects to do. The obvious remedy is to engage the services of an independent practising architect. This is done in America ; scarcely ever in England. Indeed, it is only just that I should here complement a previous remark of mine concerning the metal bridges that represent so large a share of America's contribution to bridge architecture. Not only are the United States definitely turning their back upon the extreme of temporary construction towards which a quarter of a century ago they were so gleefully speeding, but they are

setting the rest of the world an example in the meticulous care they give to the æsthetic perfection of bridge design. I do not for a moment pretend that they achieve this perfection, but they certainly appear determined to achieve it, and if they continue to extend and develop their present methods they will sooner or later shame us all. How many English railway companies, for example, employ a first-rate architect to design their bridges for them? Nor do the bridge departments (a department of which we hear little in England) of the great towns of America omit to possess themselves of the best architectural skill they can get.

An example of the earnestness with which they go to work arrives very pat to my purpose in a letter from an American correspondent. In designing the Cambridge Bridge over the Charles River, the bridge department of Boston made no less than thirty-seven designs which were compared and criticized at great length, a process which finally yielded yet another design from which the construction was carried out. And it should be noted that these were not engineering designs: they were *architectural* studies, produced solely to enable the finest possible shape to be given to the finished structure. We often hear of thirty or forty designs being submitted by different authors in a competition, but for one department to produce this number one after the other for no other reason than this is surely a more unusual occurrence. Yet this is what was done for an ordinary bridge by a municipal department. When it comes to designing a bridge of unusual prominence it is very seldom that an independent architect of repute is not called in to assist. In England this resource is so often neglected for public buildings that we shall not be surprised to find it employed only very infrequently for bridges.

Much excellent work has, it is true, been done by engineers; in particular, I may mention the bridges of the Surrey and

Herefordshire County Councils, several of which are really admirable. Though the work of engineers, they are excellent bridges none the less. Still, an engineer is, at the best, an expert in structural dynamics only, and in bridges as well as buildings there are a good many aspects to be studied and problems to be solved other than those of structural dynamics. It has fortunately become a commonplace to insist that in the design of a building the structural engineer is but one of the many expert advisers called in by the architect, whose creative intelligence must not for an instant lose control of all these subdivisions of modern building technique if the finished work is to be worthy of a place in our towns. Yet how often and how comfortably this obvious truth is disregarded we all know. In the building of bridges the disregard is even more flagrant.

To instruct the engineer in the principles of architectural design is an alternative remedy which is sometimes propounded and which indeed has occasionally yielded favourable results. It is, however, utterly wrong in principle and can scarcely be imagined to hold out a promise of any notable improvement. The engineer *qua* engineer is a person who has purposely cut himself off from the entire subject of building to devote himself only to one particular branch of it. He may not unjustly be compared to the man who assembles the piston-rod in Mr. Henry Ford's factory. He too is a specialist, and no one but a fool would ask him to design a complete motor-car. He assembles piston-rods, and in all probability he does this exceedingly well. The structural engineer will calculate you the stresses and strains of your bridge to a nicety, and will tell you with precisely how little material you may safely attempt to withstand these disruptive forces. It is foolish and unjust to ask him to do more. It is foolish and unjust to apply the principle of subdivision of labour to a building

process, and then to act as though that principle did not exist. You may try to teach your engineer something about architectural design, but his own subject is so extensive and so complicated that he cannot hope adequately to master both. There appears, then, to be nothing for it but to put an architect in charge of a bridge as he is now put in charge of a building. There are many bad buildings and many bad architects, but it is doubtful whether there are more bad architects than there are bad engineers, or bad tailors, or bad publicans. Clients and customers must always themselves be responsible for their choice of a tailor or an architect: it is a responsibility from which there is no escape. It is certainly not one which can be used as an excuse for not going to a tailor or an architect at all.

But it may perhaps be asked whether the ordinary architect, even if he be a very good one, may be expected to have a profound knowledge of bridge design? The answer is simple. The architect's training in modern times is more and more becoming inspired by a consistent logical system, and the successful student issues from it with his mind equipped to design any formal entity whatsoever, from an industrial city to a window fastening. This inventive facility which his training confers upon him does not, however, make him a Jack-of-all-trades. The rational principle of inflexion to which the preceding chapter was devoted is one that operates continuously from the smallest visual form to the largest. Formal design, no matter to what scale it is applied, constitutes one trade, one activity only, and the fact that the window-catch revolves round a spindle, and the city round a public place, does not absolve either of these from the necessity of complying with the same universal laws of form.

In support of these statements I need only point to the designs produced by the candidates for a recent Rome

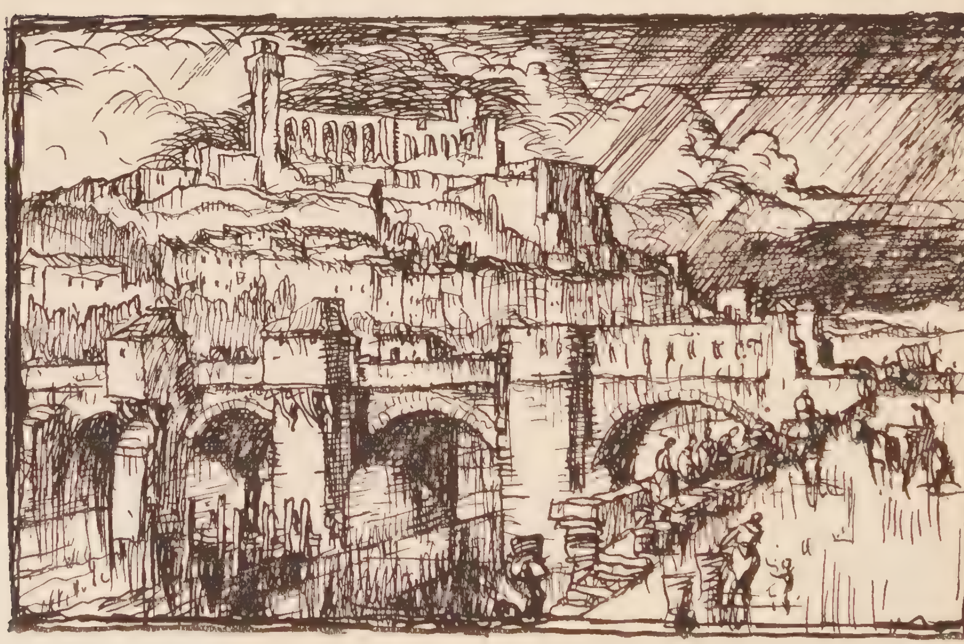
Scholarship in architecture. The subject in the preliminary contest was a carriage bridge across a ravine. The ten selected designs have been published, and there is not one among them that is without merit. They were all competent and agreeable designs, though some were indeed better than others, and their authors were architectural students several of whom had probably never designed a bridge before. It is true that all of them used the traditional materials, stone and brick. Artificial wood is a substance with which architects have yet to familiarize themselves, a task which they will not find very difficult. But there is this to be said, that it is a task which cannot be more easily accomplished than in the study of bridge design. The framework of all buildings is covered with a screen of a solid material; the framework of a bridge not invariably, and the proper design of this framework is the next subject that should engage the attention of our architectural schools. If this is done it will soon be brought within the rational system which now governs the design of all other works of architecture: it will be humanized, it will be minted with the stile of intellectual law.

For the bridge has wandered a long way from the architectural fold of which it was once so charming and honoured a member, and my last words must be a plea that the architect be empowered to call it back. He will not be able to do it in a day. The prodigal will yet for some time bear the marks of its sojourn in the boilermaker's shop; it will not at once submit to the authority of Design from which it so heedlessly broke loose. The faculty of conception moves no more quickly than it did in the heyday of Babylon and Eubœa, and the impatient renegade must be taught once more to abide its fulfilment. We often hear it said that fine architecture is the result of the craftsman's touch. It is not the result of the craftsman's touch, but of his thought. And it is

this thought that it behoves us to restore to its rightful place. Others tell us that our heart has gone out of our work, that we have exalted intelligence at the cost of sentiment. But it is not our hearts, it is our reason that we have given away—a yet more sordid boon!—in ministering to the increasing rapacity of mechanical production. Has this impoverishment shown itself anywhere more pitifully than in the bridges we build? I, for one, am inclined to think that it has not.

There are many reasons why this is so, but one of the reasons may perhaps be singled out in these last lines of my essay. Just as much as Shelley's cloud (nay, more), the bridge is entitled to claim that

> I am the daughter of Earth and Water,



but it is not, like the cloud, the nursling of the sky, it is the nursling of humanity. There is an ancient and natural blood foreign to our species that courses in its veins; it claims a distant kinship with those creatures who peopled the glades of Arcadia, the true aborigines of this earth of ours. That kinship shows itself in a hundred barely perceptible traits, while the stream that hurries on beneath the arches murmurs a perpetual reminder of an element which we can never extirpate, and which renders our ill-treatment of the bridge the more apparent and the more sinister in its results. It is this corruption of an immemorial legacy that makes our bridges witness against us in such conclusive tones. It is this legacy that may yet help us to restore our foster-child to the condition from which it has fallen, and our own creative intelligence to the place which it was meant to occupy, rousing it from the forgetfulness that now obscures its vision and makes its strength as naught.

CONCLUDING EPISTLE TO THE ARTIST

Cher Maître,

To you, the perfect eclectic, who are always wondering why some people should like only one kind of picture, or one kind of decoration, I may perhaps recount the notion of the excellent art of painting that came to me one day in a dream. I thought I saw a great scene ready set, with nothing in it except a level floor and a background of lucent sky. On this stage were assembled a number of painters, all very young, and not easy to recognize, but one of them might have been Zeuxis, for he looked a complacent ass and went about in a Greek kirtle, and another musty surel have been Il Beato Angelico, whom I think I could pick out anywhere. There was also one who resembled you very strongly ; I am almost sure it was you. Another with a broken nose might have

been Michael Angelo, but other painters may have had their noses broken for all I know, and he did not look at all like those portraits of the fiery old man with which we are familiar. Anyhow, after they had stood there a little while, asking one another for what they had been called together, and how long they would have to wait, up came Apollo, and at the sight of him they all began to cheer and to clap their hands. He, unperturbed, mounted a rostrum that I had not hitherto noticed, held up a slim white hand to request silence, and made a short but elegant speech.

The full words of his speech I have unfortunately forgotten, but what he told the assembly was clear enough. There were, he said, going to be a number of plays given on that stage, and each man present would be required to make one up and see that is was truly and finely performed. What kind of a play it was did not matter, it might be a comedy, or a tragedy, or a mystery, or a chronicle, or a hagiology, or an opera, or one of those horrid plays that are none of these but are only object-lessons in pathological anatomy. That was for each man to choose. The only trouble was, he confessed, pointing over his shoulder, that everybody would have to use the same company of actors, scene painters and stage hands. They were an excellent company, thoroughly used to one another, and entirely devoted to their work; "this," he said (for I will begin by introducing your two stage-managers) "is my good friend Pan," and at once a sound was heard as of a thousand birds piping together, and in the midst of it came the gentle stamping of a hoof. "Under him labour dryad and hamadryad, the gods of mountain, tree and forest, the nymphs and nereids and tritons, the zephyrs who push little cloudlets up and down the sky, and those older and fiercer spirits who captain the rolling clouds of storm and angry weather. Jupiter himself will sometimes help him with a

flash or two of his whitest lightning, and as for me," he bowed, "both he and you may command my services from morning till night. Your other stage-manager is at my left," he went on; and now I thought I heard the clanging of iron which may have been a trowel striking a stone, and voices of men singing a simple and manly tune.

The person upon whom the eyes of the crowd were fixed looked down with some confusion as he trod forward. Round his loins he wore a leather apron; the knees of his trousers protruded, and in his large and horny hand there swung a shining trowel that seemed much too small for the fingers that clasped it. An elegant Athenian youth who was next to him held his thumb to his nose, and from where I stood I could smell the smell of beer as it was drunk in England from the glacial age till the age of science. In fact, he was just such a man as you, Sir, have drawn and painted at all kinds of tasks for a quarter of a century, with trowel or saw, spade or hammer, or bearing heavy burdens on his back. His wife stood at his side, a little behind him, in still worse confusion; in her hand was a distaff. At this moment I happened to glance at the young painter whom I took to be you, and saw his face brightening and his look fixed upon the workman who had just stepped forward, fixed and oblivious of everything but this man. All of a sudden he started and began to elbow his way towards where Apollo and his lieutenants were standing, excitedly crying, "This is the very person I want: don't let him go away." But Apollo saw him approaching and waved his hand. "Be quiet," he said; "my friend will help you to set up your stage by and by"; and as he spoke these words everybody turned towards the youthful artist and eyed him with curiosity. They saw his excitement grow rather than abate. "Help me!" he cried. "I do not want him to help me: I want him to act in my play. He is my

principal actor: he is the entire and perfect embodiment of the main part as I conceive it. I want to speak to him."

This and other things the young painter said, but before he had gone much further there arose a murmur of protest that drowned his words, and which in its turn was suddenly silenced as Apollo's voice rang out golden and clear. "I have said," it rose with some severity, "that there is no restriction upon the kind of play that may be given here, and I will suffer no one among you to put up such a restriction. You are free," he went on, turning to the young man, "to do precisely what you like, but it is my duty to warn you that by the time you have seen some of the other plays you will probably have changed your mind." The young man shook his head angrily. "What Pan will do for you in the world of nature," Apollo resumed, speaking once more to the whole assembly, "this fellow will do in the world of man. From a barn to a temple, from the distant point of a spire to the unfolding porticos and staircases of a palace, he will put you up whatever your play requires. And while he provides the background for your actors his spouse will clothe them in the appropriate garb. Now," he concluded, "we will look at the actors themselves." At these words there was a pressing and elbowing, a tiptoeing and turning about, and everywhere a great hubbub of conversation among the painters. The man with the broken nose made his way to where the workman and his wife were standing and, muttering something in a bluff and scornful tone, pushed them aside. Some one cried, "Here they come!" and the cry was taken up by a dozen others, and as it echoed this way and that way I woke out of the dream, sorry enough to be thus interrupted, but not without remarking something that happened at the very last moment down by the front of the stage. While the crowd of painters was squeezing towards the entrance at the back two men had engaged the workman and

his wife in earnest conversation. The one who was addressing the woman seemed greatly flushed ; he was clad in splendid Venetian garments, and at his feet sat a great and exceedingly beautiful dog. The workman's interlocutor was the young man whose resemblance to you, Sir, I had already noted. He had laid his hands upon the workman's shoulders, and as he spoke to him he gazed warmly and steadily into his eyes.

Well, as it fell out they were all very glad to use him afterwards, the painters and the poets too. They have made him put up many a piece of honest scenery for them, and among these are a large number of bridges, but it was not till your play came to be given that he himself was seen on the stage. What sort of a play it is that you have fashioned it is not for me to say, nor perhaps for anyone just yet ; I can only record, in all humility, that it has moved me more than most of the plays not only of our own day (for these are usually as tedious as they are impudent) but of all times, and that in spite of the fact that you have somehow become associated with the Royal Academy. But it is of the bridges he has built that I am concerned to speak here. What sort of a part have they played in the stage-setting that the great painters have provided for their dramatic visions ? Generally speaking, two sorts of parts have been given them till now, one sort symbolical and one actual, one far-off and the other close by, one splendid and exalted and the other humble and commonplace. It is in religious painting that the bridge has gradually grown to be one of the subtlest and most highly expressive of all the emblematic devices available to the artist. Somewhere in the foregoing essay I have laid considerable stress on the importance of the *first* bridge—the first, that is, when looking from the sea landwards, but the last if you turn in the opposite direction. Now you know, Sir, how wonderfully the quattro-

centist painters have seized upon this image of the last bridge to fix the boundary between the finite and the infinite: to herald the immanence of the eternal vastness, and stand at once as a barrier to the feeble eye and a jumping-off place for the strong.

I am not speaking here of the bridge that is tucked away somewhere at the side of a landscape like a brooch half-hidden in the folds of a garment. Such a bridge may be a beautiful, gleaming thing, like the one in Sebastiano del Piombo's *Portrait of a Man* at Budapest, or, better still, in Raphael's *Virgin and Child with St. John* in our own National Gallery. And a bridge used in this decorative sort of way may achieve a still greater beauty when its lines are made to clasp a central point in the composition, as in the extraordinary *Il Presepe* of Perugino's in the Church of Santa Maria del Popolo at Rome, where the bowed head of the virgin is framed in the circle of a ruined doorway, and this enveloping curve is again echoed by the arch of a bridge standing some distance back. No, I am thinking of another sort of bridge altogether. You know how those sweet and passionate painters of early virgins and saints were always impelled to open up their backgrounds wide and let the vision roam, flying through a door or a window or any kind of aperture, across a clear or fiery sky and over hill and valley, over river and copse? Yes, especially over a river, a river winding this way and that, winding and widening away towards the sea or sky—one scarcely knows which—that lay beyond. It seems as though thus guided along stretches of magic landscape the mind's flight grew calmer, steadier, more confident and secure, moving deeper and deeper into those immensities that are at once created and conquered by the rivers that Pascal has called "*des chemins qui marchent et qui portent où l'on veut aller*." Borne by this *chemin qui marche* it presses forward until it comes to rest upon the bridge.

For there is always a bridge. Its arches of throbbing silver strained and clear it stands there to bar the way against that too happy, too spiritualized egress. Sometimes the barrier that is interposed may be darker than the surrounding area, as in our own *Raising of Lazarus*, by del Piombo. But it is always as though it said to the beholder, "You pass me at your own risk; from this journey into the empyrean there are many who do not come back, and all the rest of their lives they go about with a strange look upon their faces, as though they did not belong to this world. Better pause here awhile and then return." Jan Van Eyck has such a river in two of his most ravishing pictures—the same river, too, and the same bridge, in both; some say it is the Meuse at Liège, and some the Thames in London, and I, for my part, think they are both right. The only difference between the picture in the Louvre and that in the Rothschild collection is that in the Louvre one the aperture is full in the centre of the background, while in the other the Virgin and Child occupy the centre and only the right half of the magic vista is discernible. Giorgione's great picture in the Louvre, and Perugino's *Apollo and Marsyas*, also have such a bridge to arrest and delight the eye in the middle of the horizon. And what of Ghirlandaio's great *Adoration* in the Ospedale degli Innocente at Florence? But I need mention no others. You too will have felt, I know, how in religious painting the bridge has been exalted into a symbol of profound and exquisite significance.

Then there is the other part played by the bridge: it is that which occurs in all profane painting which depicts maritime or river scenes, boatmen or anglers, or even cattle refreshing themselves at the margin of a stream. All natural scenes are at once made homely and human when you introduce into them a piece of human architecture, and what kind of architecture could be more appropriate to a water picture than a

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bridge? Consequently we have them by the hundred, those familiar rustic things of brick more often than stone, in Dutch and French and English landscape alike. I have said that they are humble and commonplace. They are, but they certainly possess in a very singular measure the beauty that is inherent in the humble and customary in the commonplace. For there is a beauty of the small as there is a beauty of the great, and Cowper's bridge that "with its wearisome but needful length Bestrides the wintry flood" belongs to the more modest, the more immediately useful, and, let me add (for it is an important point), the more immediately perceived. You cannot turn a thing into a symbol or an exalted abstraction unless you are a great distance away from it. Think of that most felicitously named of all the world's bridges, the Japanese Kintai-kyo, or bridge of the damask girdle, at Iwakuni. Who could possibly talk of a bridge as a girdle if he were looking at it while walking over it or even (for it is one of the peculiarities of bridges that they conceal themselves from you the minute you use them) standing by its side? No, this beautiful five-arched bridge belongs to those that are seen through the window beside which a Virgin presses a dreaming Child to her breast, conversing with a kneeling bishop or saint as though she had nothing else in the world to do. Its name raises it from the sphere of human usefulness into that of creative significance, of the grave poetic light of the mind.

The poets too, though they did not enter into my dream, have used the bridge a good deal in the pictures of bright sound that they have woven for us, and like you painters they have ranged from the greatest to the smallest, from the "secret bridge" on which Wordsworth's eye reposes during his evening walk to Shelley's audacious and astounding "bridge of congregated lightning." But on the whole their use of the bridge is different from that of the painters. They do not

use it as a glowing barrier, but as a means of communication. They do not think of it as poising its arches across a road that "*porte où l'on veut aller*"; they think of the bridge itself as such a road. I will only quote the grandest of them all. You know, Sir, how the great second book of *Paradise Lost* opens with the solemn council held "At Pandemonium, the high capital Of Satan and his peers," and what a fierce and desperate debate takes place there, at the end of which it is decided that Satan shall undertake an expedition to search the truth concerning man and his newly created orb. You remember how Death unlocks for him the gate of hell, and how the bold traveller recoils at the brink of the wild abyss that was the womb of Nature and may yet be her grave, to drop ten thousand fathoms the moment he tries to rise on his outspread wings. And how Chaos and Night point him the way, and how with fresh alacrity he springs up again "like a pyramid of fire" until, after much toil, he attains the region of glimmering dawn.

With this picture the second book ends, and we take our leave of the infernal cities and of Sin and Death who paused at their gates, to meet them again only in the tenth book. For seven whole books these two creatures are lost sight of while we follow the narrative into heaven and Paradise. What are they doing during all that time? Do they remain sitting patiently at the gates of hell? And are they still sitting there? On the contrary, Milton is at pains to project his great story into the future of mankind and to give its *peripateiæ* a universal movement and a universal application. And this he does by means of a bridge. As Satan wings his way towards the earth at the end of the second book Milton leaps the whole succeeding seven books to tell us what is coming, namely that no sooner was his purpose accomplished, and the fall of man brought about, than

Sin and Death amain
Following his track (such was the will of heaven !)
Paved after him a broad and beaten way
Over the dark abyss, whose boiling gulf
Tamely endured a bridge of wondrous length,
From hell continued, reaching the utmost orb
Of this frail world, by which the spirits perverse
With easy intercourse pass to and fro,

a process which is described at length in the tenth book, and described by means of such magnificent and famous images as " Death will his mace petrific." No wonder Satan, when upon his return he descries this stupendous structure, stands admiring it for a long while, until he turns and with a proud gesture sends Sin and Death to exercise dominion on the earth and in the air, but " chiefly on man," whom they may reach easily by crossing the interstellar void upon the bridge they have made. If Satan is, as has been affirmed, the hero of *Paradise Lost*, it is this bridge that signs and seals his melancholy greatness, that makes his struggle, his qualified but effective victory, and his downfall and torture in the fruit-laden grove, find a reward and a perpetuation in the unceasing traffic of Sin and Death across the newly created way.

It is strange—is it not ?—that this greatest of all bridges in poetry should be a bridge to hell, or rather *from* hell, a true devil's bridge : indeed, much more of a devil's bridge than the simple and pleasant structures bearing that name which you, Sir, have drawn from time to time. Who will tell us of a bridge to heaven ? Alas, the greatest of all those who have written in English about the river of death will not allow that it is to be crossed by any bridge. The river is not equally difficult to cross for every one who is called thither. It has its flowings to some, and its ebbings to others ; and as for Mr. Honest, who doubtless deserved better, when the time

came that he was summoned the river overflowed its banks, and had it not been for Good-Conscience who held out his hand to him he would assuredly have perished. Bridge there was none, no not for the godliest. The only bridge to heaven of which I have ever heard is in a thirteenth-century monastery in the neighbourhood of Kyoto which it is one of my dearest ambitions to visit. And yet it may be that when I get there I shall find it to be but an ordinary bridge after all.

But I have wandered a long way from my dream of the art of painting. It ended, you will recollect, with the young man who resembled you so closely standing deep in a conversation with the humble begetter of the buildings of the world. And now that I have glanced at the use to which your fellow artists have put the bridge it will be the easier for me to describe the greatness and the novelty of your own use of it. For just as you have shown an uncommon interest in the Labourer who was left by all the others to toil obscurely behind the scenes, so you have looked in his products not for what they could give of beauty or elegance or even of symbolical expressiveness, but for what they told of him, his toiling, his hopes and fears, his strength and his weakness. It seems a long time since Carlyle complained that all the gilt volumes of history were no better than the wooden volumes of a backgammon board. What use, he exclaimed, were all the Court Calendars and Parliamentary Registers which they contained? Let some one tell him instead what the common man did, thought, suffered, enjoyed, how he lived and had his being. Were Carlyle alive to-day he would recognize in you his most devoted and illustrious disciple. All this that he so thirsted to know none has told us as clearly, as fully, as richly, as nobly, as you have told us.

But what concerns me here, Sir, is that not only have you put this obscure personage, this humble scene-shifter of the

pageant of life, in the middle of your stage, but you have made his works speak of him with an eloquence that had not hitherto been thought decent or even possible. And as for the bridge, you have conferred upon it a signal honour among the multitude of those works. You have put it in the foreground of your picture, this lofty and mysterious creature born at the hands of man, and have searched deeply into its lineaments too for all that they held of his likeness. You have journeyed through most of the countries, have stood by most of the rivers, of the world, and looked upon more bridges than any man alive. And these you have drawn for us not as an inspired antiquarian like Piranesi drew them, but as Carlyle's ideal historian might have given them to us had he digressed (as he would have been bound to digress) into portraiture. For painting is not akin to history proper, though it is able to give the spectator a compendious view of a stretch of history as in a series of superposed strata. Its descriptive power can *suggest* the movements of history, but it cannot follow them in their swift and intricate sequence. They are implied in it. And what Rembrandt has done for human beings you have done for bridges. Other painters have drawn inanimate objects for the sake of other things ; you were the first to draw them for their own sake. You have invented a new kind of portraiture, and you have chosen for its subject that piece of human architecture which is most worthy of individual commemoration, most susceptible of individual analysis, most remarkable for its qualities of singleness, of intellectuality, of expressive power.

Having assembled another collection of such portraits you have done me the honour, Sir, of allowing my essay to be adorned therewith. It is an honour of which I am profoundly sensible ; all the more sensible, indeed, in that I too have attempted to live up to Carlyle's great precept, and

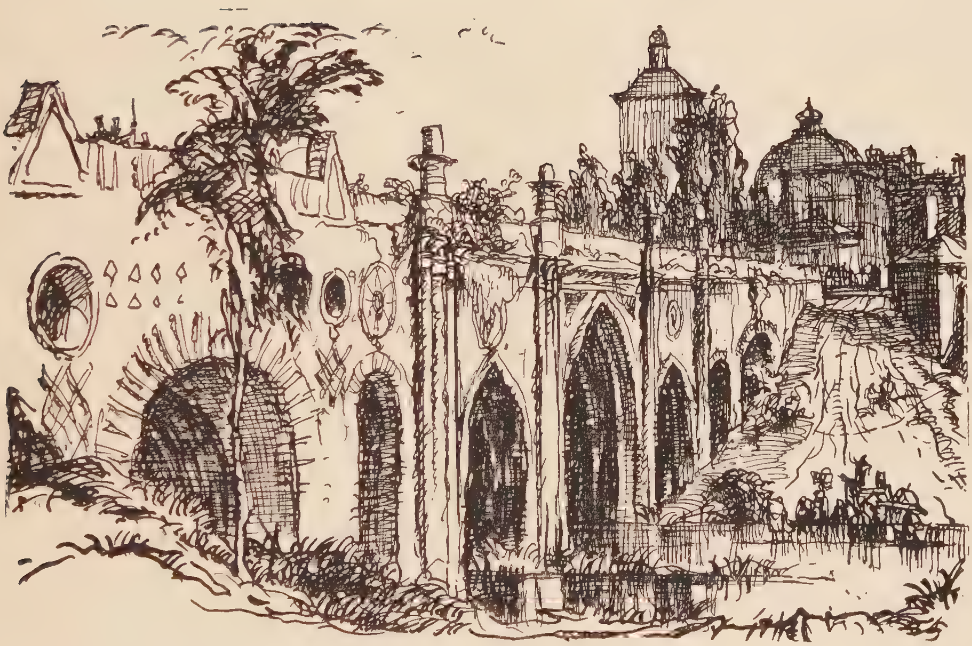
therefore know something of the difficulties that encompass it. For the bridge is no more at home on the exalted plane of Court Circulars than the mason who cut and dressed its stones. I too have tried to follow from the palace into the market-place, to forget that there ever were such things as princes and generals, thrones and battlefields, or indeed anything at all except bridges. Now the common man, the soldier and the ploughman, and even the ploughman's wife, are already receiving at the hands of many skilled historians the treatment demanded for them by Carlyle. As I write these lines a book is sent to me whose writer states it as an accomplished fact that modern history has ceased to be dazzled by the " special efflorescences of civilization " which were so far from controlling the course of that civilization. Alas, the inanimate works of man have not yet entered into this historiographical millennium. The historian who writes of them still has to make his escape from the superior attractions of the special efflorescences. It was quickly brought home to me, therefore, that I would have to set about my work in a soil that had thus far been but poorly cultivated. I will not say that none had been there to turn it up before, but the majority of my fellow-workers were (and had been for some time past) gathered very thickly about the efflorescences, by which I must own that I too am continually captivated in a measure that I should blush to tell of. But in the preceding pages I have made a resolute attempt to turn my back on them and to follow Carlyle's instruction and your own example—at some distance, it may be thought, but still, to follow. The task has been a delightful one, and its result I honestly believe to be not altogether nugatory. May I hope, Sir, that it will give you back a little of the pleasure I have derived from your drawings ?

The emperor Commodus is said to have been so absent-minded that many of his letters contained only the word

Vale. Absent-mindedness is a common failing, but if I be one of its victims its effect upon me has been the reverse of this. The one word still lacking to this letter I now hasten to subscribe, ever remaining, *cher maître*,

Your dutiful servant,

THE AUTHOR.



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